THE

AËRONAUTICAL JOURNAL

(FOUNDED 1897 in succession to the ANNUAL REPORTS)

The Organ of the Aëronautical Society of Great Britain

Telephone:
9761 CITY.

Telegrams:
"DIDASKALOS, WESTRAND, LONDON."

EDITED FOR THE COUNCIL BY
BERTRAM G. COOPER, A.F.Aë.S.

Published Quarterly

Subscription per Annum, post free, 6s. 6d.

All Communications should be addressed to—
THE EDITOR, 11, Adam Street, Adelphi, W.C.

No. 66. APRIL, 1913. VOL. XVII.

Notices of the Aëronautical Society of Great Britain

GENERAL NOTICES

February Elections : Associate Members :—LIEUT.-COL. F. C. MASSY and LIEUT. T. H. S. MONTEFIORE, R.H.A.

Student :—RALPH RICHARDSON.

March Elections : Member :—CAPT. H. MUSGRAVE, R.E.

Associate Member :—BRIGADIER-GENERAL C. PENROSE, C.B.

April Elections : Members :—MAURICE DUCROCQ and C. R. FAIREY.

Associate Members :—CAPT. S. W. BEEMAN, COL. FERGUSSON, the RT. HON. THE LORD SAYE AND SELE, LANCELOT L. VIGERS.

¶ **Council Election :** As the result of the recent election, the Council for 1913-14 is composed as follows :—Associate Fellows : A. E. BERRIMAN ; GRIFFITH BREWER ; COL. J. E. CAPPER, C.B., R.E. ; T. W. K. CLARKE ; J. W. DUNNE ; J. H. LEDEBOER ; MAJOR E. M. MAITLAND ; W. O. MANNING ; F. K. MCCLEAN ; ALEX. OGILVIE ; MERVYN O'GORMAN ; F. HANDLEY PAGE. Members : LIEUT. R. GREGORY, R.N. ; COL. H. E. RAWSON, C.B., R.E. ; MAJOR-GENERAL R. M. RUCK ; MAJOR F. H. SYKES.

¶ **Election of Chairman :** MAJOR-GENERAL R. M. RUCK, C.B., R.E., has been elected Chairman of the Council for 1913-14.

¶ **The late Sir Charles D. Rose, Bart., M.P.** On the death of the late Sir Charles Rose, Chairman of the Royal Aero Club, the Council passed the following resolution which was communicated to Lady Rose :—

" The Council of the Aeronautical Society of Great Britain, having heard with great regret of the death of Sir Charles D. Rose, desire to extend the deepest sympathy of the Society to his family in their sad bereavement."

¶ **Appointment of Committees :** The following Committees have been appointed :—

(1) Inventions Committee (which deals with inventions submitted for the Society's opinion) : T. W. K. Clarke, B. G. Cooper, Col. H. E. Rawson, C.B., R.E.

(2) Finance Committee : Griffith Brewer, J. H. Ledeboer, F. Handley Page, Major-General R. M. Ruck.

(3) Library Committee (which has charge of the Society's library and records) : H. F. Lloyd, B. G. Cooper.

(4) Relations Committee (which treats, when occasion arises, with other aeronautical bodies) : A. E. Berriman, B. G. Cooper, F. Handley Page, Major-General R. M. Ruck.

(5) Research Committee (which conducts the research work of the Society in all its branches) : Harris Booth, T. W. K. Clarke, B. G. Cooper, Col. J. D. Fullerton, B. Melvill Jones, Archibald R. Low, Mervyn O'Gorman, F. Handley Page, A. P. Thurston.

Representatives : The following have been appointed to represent the Society on the Accidents Investigation Committee : A. E. Berriman, J. H. Ledeboer, Mervyn O'Gorman.

¶ **Hon. Assistant Secretaryship :** This post has been discontinued for the present.

¶ **Library :** The Council desires to thank Mr. Eric H. Clift for the gift of a set of eight aeronautical maps, *Aerodrome to Aerodrome*, and Mr. T. W. K. Clarke for the gift of an 8 ft. mahogany propeller.

¶ **Ghent International Exhibition :** By arrangement with the Board of Trade the Aeronautical Society have lent the Pilcher Glider and a collection of old prints, photographs, and posters, for exhibition in the British Aeronautical Section of the Ghent International Exhibition.

¶ **Wilbur Wright Memorial Lecture :** The first Wilbur Wright Memorial Lecture will be delivered by Horace Darwin, F.R.S., at the Royal United Service Institution, Whitehall, on Wednesday, May 21st, at 8.30 p.m.

Preceding the Meeting, the Council will entertain the Lecturer and other distinguished guests at dinner, at the Whitehall Rooms, Hotel Metropole, at 7 p.m. precisely.

Members desirous of contributing to the Guarantee Fund, and so joining the Council as hosts of the evening, are invited to subscribe for dinner tickets at two guineas each, inclusive of wine. Members can bring guests at one guinea each, and it is hoped that several ladies may be present both at the dinner and at the Lecture.

BACK NUMBERS OF JOURNAL WANTED

Any members possessing the undernoted copies of the Journal and willing to dispose of them are requested to communicate with the Secretary, 11, Adam Street, Adelphi.

April, 1897.
January, 1899.
April, July, October, 1903.
January, July, 1904.
July, 1905.
April, July, October, 1906.
April, 1907.
January, October, 1908.
January, July, October, 1909.
January, July, October, 1910.
January, April, 1911.
January, 1912.

OBITUARY

THE EARL OF CRAWFORD AND BALCARRES

We regret to announce the death on 31st January of the Right Hon. the Earl of Crawford and Balcarres, K.T., F.R.S., aged 65. He was a life member of the Society and served on the Council for some years.

LIEUTENANT-COLONEL F. C. TROLLOPE

A pioneer of military ballooning passed away in Lieut.-Col. Trollope, who died suddenly of pneumonia on 28th January, aged 55.

In 1877 he was gazetted to the Grenadier Guards. In 1884 he went to Bechuanaland (with Sir Charles Warren) with a balloon detachment, and was in close touch with aeronautics until his death. He was concerned with the construction of the first British military dirigible, assisted in founding the Aero Club, joined the Aeronautical Society in 1902 and served on the Council for several years, was a Vice-President of the Society and past-President of the Kite and Model Aeroplane Association, and was always ready to assist aeronautics by all means in his power. He rendered invaluable services to the Society and his loss will be keenly felt.

PERCIVAL SPENCER

Percival Spencer died on Friday, 11th April, aged 49. His connection with the Aeronautical Society goes back to the year 1897.

He was a man of sound judgment and cool in the presence of danger. His sense of proportion and of justice were admirable also.

When I first met him, he had returned from a tour of India, China, and Japan, where he had been astounding the inhabitants by jumping into space from a balloon from a height of many thousand feet. In those days this feat appeared nothing short of miraculous, to be classed with walking on water or passing unburnt through a fiery furnace, and it is small wonder that those who saw the sight of a man coming down from the sky with nothing but an umbrella without its frame to hold to, attributed to him divine powers. His coolness on several trying occasions brought him safely through many adventures, and in the spring of 1891 he arrived home in London and took charge of the balloon ascents at the Naval Exhibition at Chelsea. It was there that I first learnt to appreciate his many sterling qualities.

The first ascent I made with him stands out in my memory as illustrating much of his character. Mr. Patrick Y. Alexander was my fellow passenger on that occasion, and the day was rainy, with a rough westerly wind. The balloon, soaked with water and loaded with its three occupants, would lift but one spare bag of ballast in addition to a bag of valuable instruments. The clouds scudding to the eastward towards the mouth of the Thames were so low that the ground was lost sight of almost immediately on leaving the Exhibition. We passengers were raw novices then and Mr. Spencer had to judge the

risks entirely alone, and when the roar of London faded into the distance he opened the valve and we came into sight of the ground bowling along at the rate of thirty or forty miles an hour. The solitary bag was poured out to avoid striking the spire of Bexley Heath Church, we crossed over High Street, threw the grapnel in the back garden of a shop, thus lightening the car sufficiently to enable it to clear the wall and demolish a pigsty on the other side. The balloon then rolled round, taking off tiles and chimney pots from the adjoining houses, and ultimately became piled up on the muddy ground. When we rolled it up we found a man lying beneath the balloon overcome with the gas, and I immediately drew a knife in order to release him by cutting the net.

Mr. Spencer stopped me doing this, and drawing back the net he released the man through the doubles without cutting it. The man revived in a few minutes and was none the worse for his experience of being gassed.

This is a typical example of Mr. Spencer's appreciation of proportion. He might have thrown Mr. Alexander's bag of instruments away as ballast and so secured a more suitable landing place, and by cutting the net the man could have been released a few seconds earlier. But after-events proved that neither of these sacrifices were necessary, and his cool judgment secured safety without unnecessary loss.

Percival Spencer possessed great patience and could bear misfortune with fortitude. Unfortunately, his business methods were not in harmony with many of his old ballooning friends, but although this caused him some pecuniary loss, he bore no resentment on that account. It is therefore with the greatest sense of loss that his old ballooning friends and pupils heard of the death of the pioneer of modern ballooning.

GRIFFITH BREWER

THE MATHEMATICAL THEORY OF AEROPLANE STABILITY

REPLY TO DISCUSSION

BY E. H. HARPER, M.A.

On the relations between mathematical theory and experiment in the solution of the problem of stability I will only say that I agree in general with Mr. Low, Mr. Handley Page and Mr. Clarke. Professor Bryan deals with this point in his remarks on the discussion.

Though the theory of the small oscillations of an aeroplane about a state of steady motion in a straight line does not explain everything, it is useful for its own purpose—to find out how to make the oscillations small. The limitations within which it gives approximately correct results is a question for experimental determination. Plotting the air-forces and couples for different values of u, v, w, p, q, r, the range within which the graphs approximate to straight lines can be found.

Mr. Clarke, from his own point of view, goes too far, when he says that *all* four roots of the biquadratic should be zero. In practice the short longitudinal oscillation seems to escape notice, and it might be true that it is difficult or impossible to fly an aeroplane in which this oscillation is not well-damped. With regard to the lateral oscillations, the spread of the wings damps rolling, and evidently veering and sideslip are resisted by the body of the aeroplane, therefore only one root of the biquadratic can be zero in practice.

As was pointed out in the discussion, the determination of the resistance derivatives is the crucial point in the mathematical theory. It is evidently simpler to find their values experimentally for a complete aeroplane than to calculate them for each part, even if rules for such calculation were available.

The damping of the long longitudinal oscillation depends on the ratios of d, l, and $\sqrt{\frac{k^2 S^1 + \sigma}{2 \sigma}}$. d is wing loading in the absolute. In connection with Mr. Clarke's example it is interesting to note that when the damping approaches its maximum

$$\frac{U\lambda^1}{g} = \tan\gamma \cos\theta + \tfrac{1}{2}\sin\theta.$$

where γ is the angle of gliding. If this angle is one in six the stability would not fall off much in ascending at an angle of one in ten, but if the damping is not so good in horizontal flight it is more seriously affected in ascending.

The expression for l referred to by Professor Hill is an approximate value under particular circumstances of the more general value given at the top of page 16. The latter expression in its turn only applies to a neutral tail when the shift of the centre of pressure on the main plane can be neglected. I cannot produce any experimental evidence in support of the theory, but it suggests at any rate that the damping may be decreased by putting the tail more than a certain distance behind.

Denoting by e the shift of the centre of pressure per radian change of the angle of incidence, in the case instanced by Mr. Handley Page, e is a little greater than the chord if we assume the shift uniform between 0° and 10°. e is negative if the corresponding couple opposes the righting action of the tail. For stability $\sigma l + S^1 e\mu$ must be positive. The effect can in part be represented by changing the value of d to d^1 where

$$d^1 = d\ (1 + S^1 e\mu/\sigma l)$$

The equation of the short oscillation becomes :—

$$\left(\frac{U\lambda}{g\cos\theta}\mu\right)^2 S^1 k^2 + \frac{U\lambda}{g\cos\theta}\mu\,(S^1 k^2 + \sigma k^2 + \sigma l^2) + \sigma l\ (l + d^1 - e\mu)$$

The period of the long oscillation is given by :—

$$\left(\frac{U\lambda}{g\cos\theta}\right)^2(l + d^1 - e\mu) + 2d^1 = 0.$$

The part of the modulus of decay of the long oscillation independent of head-resistance becomes :—

$$\frac{U\lambda^1}{g\cos\theta} = \mu\frac{\left(1-\frac{e\mu}{d^1}\right)^2 - \frac{e\mu l}{d^{1^2}} - \frac{k^2}{l\bar{d}^1}\frac{S^1+\sigma}{\sigma}}{\left(1+\frac{l}{d^1}-\frac{e\mu}{d^1}\right)^2} + \frac{d^1}{l+d^1-e\mu}\frac{\tan\theta}{2}$$

From an inspection of these equations it is evident that unless d^1 is small the terms in $e\mu$ may be neglected and the alteration in the value of d gives approximately the effect of the shift of the centre of pressure. When, however, d^1 is small, that is when e is negative and the effect of the tail is barely sufficient to overcome the unstabilising effect of the shift of the centre of pressure, the terms in $e\mu$ must be taken into account in finding the modulus of decay of the long oscillation. It should be noted too, that the rotary derivatives of the main plane are probably of the same order as the effect of shift of centre of pressure and so the results in the latter case would not be of much practical importance.

Mr. Berriman's sketches represent diagrammatically my conclusions on the effect of the dihedral. I cannot say whether the rudder actually does satisfy the condition for the tail fin, but there seems to be no reason why it should not. My remarks on stabilisers dealt with an imaginary aeroplane consisting of a straight plane and stabilisers alone. In an actual aeroplane the total fin effect of all the different parts would have to be considered, and down-turned wing tips set at a negative angle of incidence in conjunction with fins or equivalent fins elsewhere might produce stability. The damping of rolling by the spread of the wings referred to by Mr. Berriman is represented mathematically by the derivative L_p. Each of the resistance derivatives, in fact, has a definite physical meaning and the notation L_p shows that this is the coefficient of the couple about the longitudinal axis produced by a rotation about the same axis. A reference to the table on page 19 shows that it is much greater than any of the other derivatives. The lateral displacement of the centre of pressure would be represented by the value of L_w for the plane, but data for the investigation of its effect are wanting.

The superiority of wing tips to fins noticed by Mr. Handley Page may be due to two different causes. With wing tips the equivalent fin may be placed much higher or further in front than an actual fin could be attached. In addition, though the w and p derivatives are the same for stabilisers and the equivalent fin the q derivatives are different. By retreating the wing tips to a greater or less extent some adjustment may be made which is impossible with fins. Probably it is the value of L_q (the couple about the longitudinal axis produced by veering) that is of practical importance.

In conclusion I wish to thank the speakers for their careful consideration of the paper and their helpful criticism

REMARKS ON THE DISCUSSION

BY PROFESSOR G. H. BRYAN

In reading the discussion on Mr. Harper's paper I cannot help reiterating the view that I have previously expressed, that it is a great pity that these difficult mathematical investigations could not have been completed at a far earlier stage in the development of aeroplane flight.

This is the view which I tried to bring forward at the ill-fated Sheffield discussion in 1910, and it was a great misfortune that my pleas were misunderstood, and that the hostile criticisms rendered it even more difficult than before to arrive at an understanding regarding the relations between "theory" (so called) and practice in connection with this problem. Colonel Fullerton, Mr. Low, Mr. Handley Page and Mr. Clarke seem to

have, I am glad to say, formed a pretty correct estimate as to what we think that our investigations ought to do and what we should never think of claiming for them, and both these aspects of the problem are equally important.

It might possibly be a fair analogy to suggest that the "systems of narrow planes gliding at small angles" described in "Stability in Aviation" stand in much the same relation to an actual aeroplane as Carnot's perfectly reversible cycle to an actual steam or gas engine. The same objections could be raised to both. In either case the mathematical investigations assume conditions that are different from the complex conditions occurring in actual practice. But I really do not see how the efficiency of heat engines could have been properly investigated without having Carnot's cycle to fall back on as a standard of comparison, and whatever be the final solution of the practical problem of stability, I think that a similar standard of comparison is here necessary, based on an application of the principles of rigid dynamics to a system of planes moving in an assumed medium satisfying assumed laws of resistance.

There are two points in the discussion that merit attention. Colonel Fullerton expresses the opinion that we may safely neglect the rotary derivatives; on the other hand, Mr. T. W. K. Clarke points out that we cannot neglect the lateral shifting of the centre of pressure due to a small sideways velocity.

With regard to the first point, I wish I could feel that we were on the safe side in neglecting the rotary derivatives, for I have always felt that we should *not* be on the safe side unless we recognised their possible existence. If it can be shown experimentally that they are negligible I shall only be too delighted to consign them to oblivion. But Colonel Fullerton's contention, that these effects vary as the *square* of the angular velocity (in which case they would be neglected in a study of small oscillations), does not seem to be in accordance with *general* methods of reasoning. If we assume the principle that resistance varies as the square of the velocity, then the six force- and couple-components acting on any body or surface will be homogeneous quadratic functions of the six velocity components U +u,v, w, p, q, and r, and if we expand by Taylor's Theorem we get a term containing U^2 followed by *first powers* of u, v, w, p, q, r multiplied by U. Moreover, two narrow planes ,one behind the other, if treated as one system, certainly have rotary derivatives, and the same must evidently apply to a broad plane, whose breadth is comparable with the distance between the narrow planes.

I have dealt with this question of rotary derivatives at great length, because I am of opinion that from the very nature of the case *the question cannot be decided except by actual experiments*, and it is a question which *may, unless proved to the contrary*, greatly affect the safety of aeroplanes.

With regard to flexible bird wings, if Colonel Fullerton considers these are the best means of securing stability I hope that he will have no difficulty in forming some rough and ready estimate of their effect on the stability coefficients and seeing how the equations work out when these are taken into account. Then it will be seen how far these really give the necessary stability.

Now, with regard to Mr. Clarke's lateral shifting of the centre of pressure, I admit that we assumed that this might be neglected. But it is quite easy to introduce the necessary terms into the equations and thus to ascertain *what effect* such a displacement would have on stability. I fear that some people do not quite understand the proper use of a deduction from previously stated assumptions which do not agree with experiment. The conclusion to be drawn is that the divergence is due to the causes which were neglected in the deduction. So far from being a failure, the deduction has pointed out the proper direction in which a relation between cause and effect has to be sought.

With reference to gyrostatic action and propeller torque, surely it may be left to practical men to get rid of these objectionable influences by proper balancing and use of tandem screws revolving in opposite directions. I alluded to this question recently in a review. It is a mere reapplication of the principle of the compound turbine.

But I still think it remarkable that aviators have had to wait so long for these discussions on determinantal biquadratics followed by a long list of unsolved problems. Electricians had all the mathematics done long before they applied electricity to lighting and traction. Of course, borough electricians do not use spherical harmonics and conjugate functions, but all these things are elements in the development of electrical science. I

do not at all agree with Sir George Greenhill's view, that we can take our time over these studies to an unlimited extent without any hurry. I drew attention to the problem of stability fifteen years ago in Science Progress, but for more than ten years after we had not time to think of much except teaching and examining our pupils. In the meanwhile there was plenty of time for some Smith's Prize candidates to do what we have now done, and to have these difficulties cleared up before anyone went up in the air. Had this been done the practical engineer would have been the master of the whole situation by now. The only reason I can suggest is the decay of the study of Applied Mathematics referred to by Dr. L. N. G. Filon in his recent report to the Board of Education's Advisory Committee. Possibly the spirit shown in the Sheffield controversy also acted as a deterrent to some weak-kneed budding mathematicians. It certainly caused delay of nearly a year in the appearance of "Stability in Aviation."

But we on the mathematical side are faced with another difficulty, in that we receive numbers of books and papers (the latter often published in well-recognised technical journals) in which questions regarding aviation are treated with a wealth of unnecessary formulæ and a supreme disregard for such principles of elementary mechanics as are taught in a school or first-year university science course. I have before me a book on "Aeroplanes in Gusts," by S. L. Walkden, which seems to me to be based on a total misconception of the physical significance of the Parallelogram of Accelerations, also a French book, "La Théorie de l'Aviation," by Robert Gaston, in which the author obtains and applies a result which is contradictory not only to the equations of accelerated motion but also to conclusions he himself previously established. And yet M. Maurice Farman writes a preface congratulating the author on the clearness and simplicity of his treatment! We cannot run the risk of being called on to waste our valuable time in controversial discussions with the authors of papers of this kind, and so we have to keep a good deal in the background.

I fully agree with Mr. Handley Page in thinking that the proper course to pursue is to determine stability coefficients for a machine considered as a whole, by experimenting on a model placed in a wind-tunnel. There are various ways in which such a model could be attached to pendulums in such a way as to obtain values for the longitudinal and the lateral derivatives. When this has been done the model could be flown and a comparison effected between the two independent methods of observation. But here again you require mathematical formulæ to interpret your pendulum experiments, and these have not yet been obtained. This method would, of course, supersede much of the work in our book as far as actual aeroplanes are concerned. But I have been told by surveyors and others that they attach much importance to the "outlook value" of a mathematical training even when they do not use the actual formulæ in their professional work, and I think the same may hold in connection with the study of narrow planes at small angles.

A college course for specialists wishing to take up aviation would include a great deal of physics, a thorough knowledge of calculus, differential equations, solid geometry, and particularly particle and rigid dynamics, the latter leading up to a study of the simpler cases treated in "Stability in Aviation" and many of the unsolved problems detailed therein when they have been solved and published.

A great deal of money is now being spent on "research" endowments for work having no direct bearing on any practical applications of immediate interest. It would be a great advantage if some of these funds were used to quickly clear off our accumulation of "unsolved problems." An absurd waste of such funds occurred recently when they were applied to testing the degree of accuracy to which g could be found with Atwood's machine, although it ought to have been known all along that this "machine" could never be as effective as other methods. The holders of research endowments are not allowed to undertake teaching work, and they receive salaries not far short of those of an assistant lecturer. Mr. Harper's investigations have had to be performed on the top of a large amount of teaching work. Although I am tired of repeating the opinion, I again ask, cannot something be done to complete these remaining preliminary mathematical investigations?

THE FOURTH MEETING of the Forty-eighth Session of the Aëronautical Society of Great Britain was held at the Royal United Service Institution, Whitehall, S.W., on Wednesday, 15th January, 1913, at 8.30 p.m. Professor W. C. Unwin, F.R.S., presided.

THE CHAIRMAN: My duty in introducing the Lecturer is a merely formal one, as I have no practical experience in aeroplaning. Obviously in the very important advance made in flying the art has gone ahead of the science. That is a common experience. Ships were used long before questions of stability were investigated. But a point has been reached at which science can aid the art, and some of the questions requiring scientific investigation are definitely posed and material for their solution is accumulating. This paper deals with one branch of the subject of the greatest importance, namely, the strength required for safety in the structure of the aeroplane. It is a pleasure to be allowed to introduce the Lecturer.

THE COMPARISON OF MONOPLANES AND BIPLANES

WITH SPECIAL REFERENCE TO THE STRESSES IN EACH TYPE

BY F. HANDLEY PAGE, A.F.AË.S.

1. General Outline

During the past year the question as to the relative advantages of monoplane and biplane types has been brought very much to the fore owing to the unfortunate accidents that have occurred—the accidents in this country being all on the monoplane type of machine. In the present paper a comparison has been made of the stresses set up in the various parts of the two types, so that conclusions might be drawn as to the limits, if any, between which each type was most suitable. A further note is included giving a short comparison as to their respective aërodynamical qualities, so that the whole survey might be as complete as possible.

The biplane type has been divided into two classes dependent on the type of bracing employed for staying the main panels of the planes.

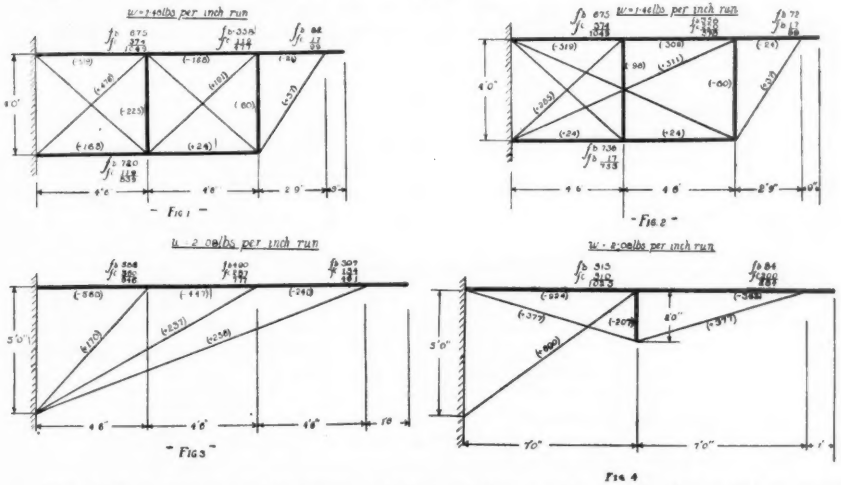

Fig. 1 is a diagrammatic representation of the case in which the ordinary cross bracing of each panel is used.

Fig. 2 of the case where the main cables have their anchoring in the body.

The first type is more applicable to biplanes of small span than the second.

The monoplane type has similarly been divided into two classes, also depending on the method of present use. Fig. 3 shows what I have termed the ordinary bracing as used on the Bleriot, Deperdussin, &c. Fig. 4, the bracing employed when a king-post is used, as in the old Antoinette machine.

2. Method of Analysis

In any ordinary aeroplane structure of present-day type the stresses that are met with are either simple compression or tension as in the struts or stay wires respectively of the machine, or there may be a compound stress as in the case of the main spars of the plane where there is combined compression and bending. This latter case, which is the equivalent of a strut with a lateral loading, has been very ably dealt with by Professors Perry and Morley*. It is here only necessary to give the results obtained, which, in the approximate form suggested by Professor Perry, are as follows :—

The maximum bending moment due to the compressive force in the top spar

$$M_0 = M \times \frac{P_e}{P_e - P} \qquad (1)$$

where M = bending moment due to air pressures and fixing moment, and

P_e = Euler's limiting value for ideal struts, depending on :—

I, the moment of inertia of the strut cross section about an axis through its centroid perpendicular to the plane of flexure ;

E = Young's modulus ;

P = The compressive force in lbs. action on the spar ends ;

A = Area of cross section in square inches.

The maximum intensity of bending stresses for a spar of symmetrical section is—

$$P_b = \frac{M_0 d}{2I} \qquad (2)$$

where M_0 and I have the same values as before and d = depth of spar in inches.

Hence, the maximum intensity of compressive stresses in the top spar is—

$$f_c = \frac{M_0 d}{I} + \frac{P}{A} \qquad (3)$$

The maximum intensity of tensile stress in the lower spars of a biplane will be represented by the same formulæ, but in this case the part of formula (1) which deals with the force reads —

$$\frac{P_e + P}{P_e}$$

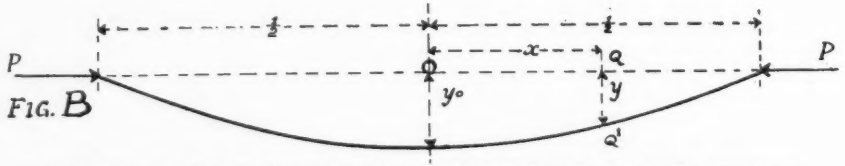

FIG. B

The diagram in Fig. B gives the meaning of the various factors in the equations.

It is now only necessary to consider particular cases and, for each one, to determine :—

(1) The loading on each part of the plane, including the simple compression and tension stresses in struts and stay wires.

(2) The shearing force.

(3) The bending moment.

(4) The maximum intensity of stresses for any portion of the plane spar.

The above reasoning would only apply to machines similar to the Bréguet, in which practically all the load is taken on one wing spar—in the case of this machine a round steel tube. In other types, where there is both a front and back spar—each carrying a large proportion of the load—the amount carried by each must be calculated so that the stresses in each can be accurately found. This is a simple matter if the movement of the centre of pressure is known for different angles of inclination. In the diagrams the force shown is the total amount for the two spars.

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* Prof. J. Perry, *Philosophical Magazine*, March, 1892.
J. A. Morley, *Philosophical Magazine*, June, 1908.

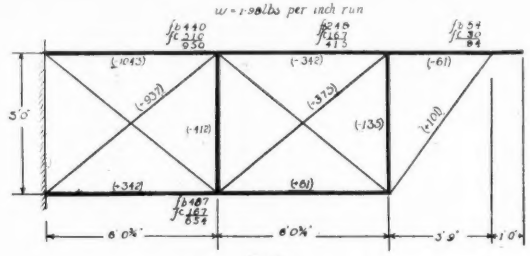


FIG. 5

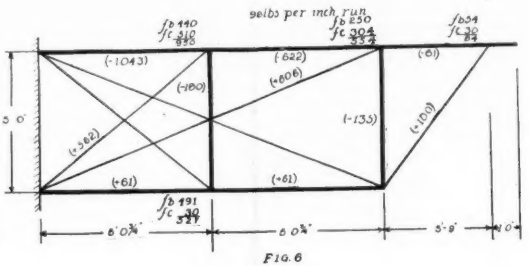


FIG. 6

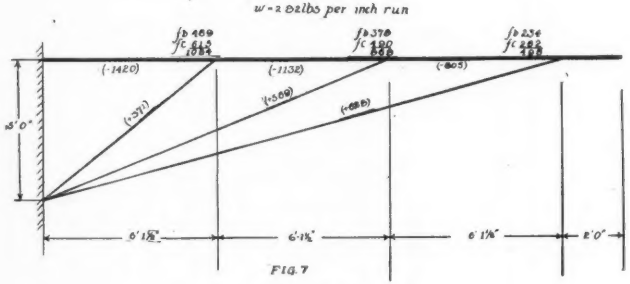


FIG. 7

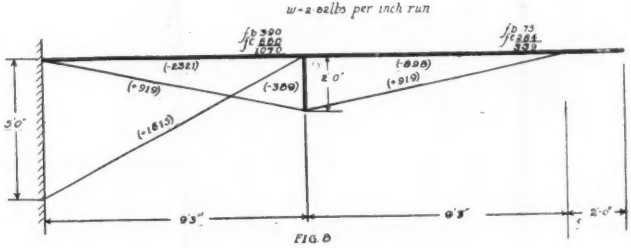


FIG. 8

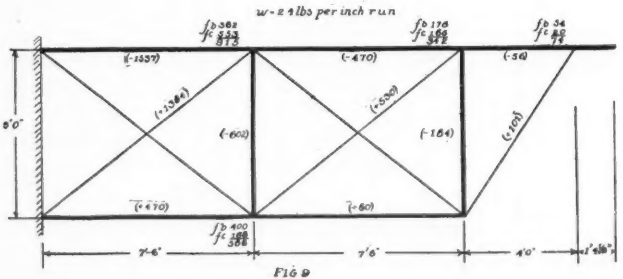


FIG. 9

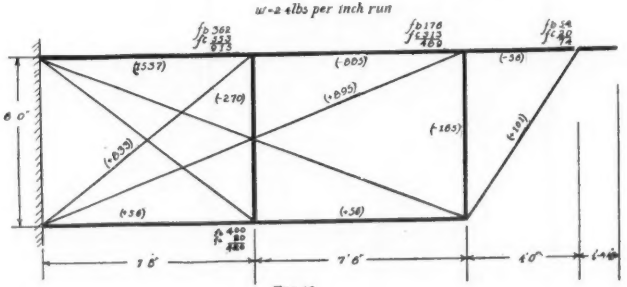


FIG. 10

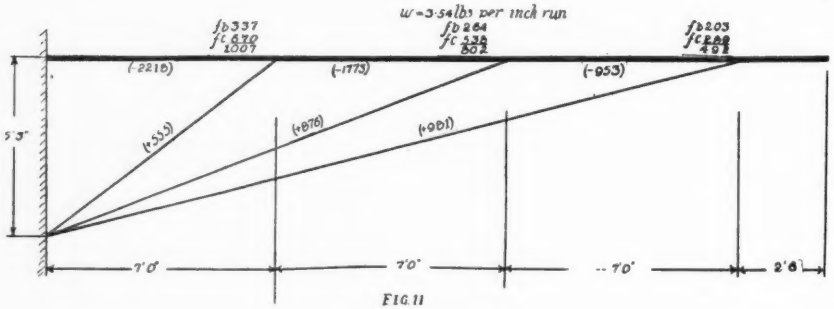


FIG 11

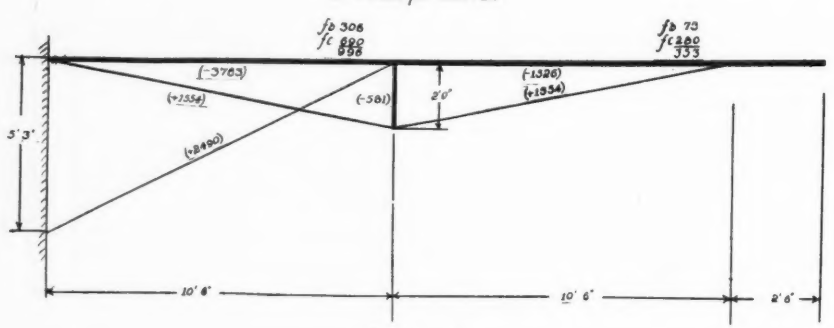


FIG 12

The stresses set up in the ribs of the machine have been dealt with separately after the general consideration of the plane spar stresses.

3. Examples of Machines considered

In order to make the presentation of the subject as clear as possible, three cases have been calculated for both monoplane and biplane. In each an allowance of 5 lbs. average lift per square foot of surface of the planes has been assumed, so that for both monoplane and biplane practically the same range of speed variation and climbing power is obtained for both types. This is not strictly accurate, as will be explained later, when the modifications necessary owing to this assumption are discussed.

The central body of the machine has in both cases been excluded, and the span of the machine taken to be nearly the span of the planes themselves. This assumption does not materially affect the result.

The three cases calculated are as follows :—

(1) Machine with 150 square feet area.
(2) Machine with 275 square feet area.
(3) Machine with 400 square feet area.

The corresponding lifting capacity of each type is, on the 5 lb. per square foot lift assumption, respectively :—

(1) 750 lbs.
(2) 1,375 lbs.
(3) 2,000 lbs.

The dimensions of each type are set forth in the following table :—

4. Sizes of Machines Considered

Type.	Area.	Span.		Chord.
		Top Plane.	Lower Plane.	
Monoplane	150 sq. ft.	30′	—	5′
Biplane	150 sq. ft.	25′	18′	3′ 6″
Monoplane	275 sq. ft.	41′	—	6′ 9″
Biplane	275 sq. ft.	33′ 9″	24′ 3″	4′ 9″
Monoplane	400 sq. ft.	47′	—	8′ 6″
Biplane	400 sq. ft.	40′ 9″	29′ 3″	5′ 9″

There are twelve diagrams for the six machines shown in Figs. 1—12. Each biplane has been calculated for both panel and monoplane bracing, and each monoplane for the ordinary and for king-post bracing. This division has been already referred to above.

5. Method of Comparing the Results

Comparison may be readily effected between the forces of simple compression or tension that exist in any members of either size of machine. When the case of the combined stress is considered there is a difference. The amount of increased compression or tension, due to the lateral load, depends on the section of the spars used. A small assumption must be made at this point to present the facts clearly. A spar of constant thickness of flange and web but of varying depth has been used in each case. The various depths of spar that are required for the different cases enable an idea to be formed as to the relative limits and advantages of the various sizes from the point of structural considerations.

For a machine of given area, and in this paper, therefore, of given load, the vertical force will be the same for both monoplane or biplane, although the dispositions thereof may be somewhat varied. The figures for these have not been included in the diagrams. The forces existing in the stay wires or struts of a machine, due to the vertical force, are much smaller than those in the longitudinal members. The limits, therefore, of a given type are rather to be found in the sizes of the horizontal spars than in the vertical ones. On each diagram the following figures are given :—

(A) The loading per foot run.

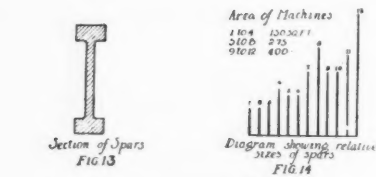
(B) The tension or compression in each horizontal member due to the action of the stay wires.

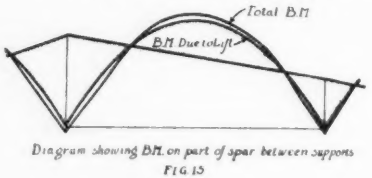
(C) The intensity of stress in the spar cross-section due to :—

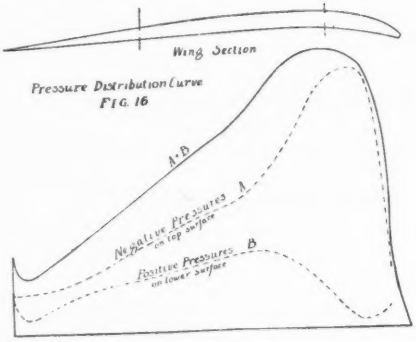
(1) The simple compression in the spar. This is denoted in the diagram by the letter C.

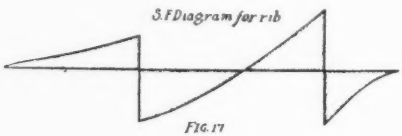
(2) The intensity of stress due to the lateral force. This is denoted in the diagram by the letters B M.

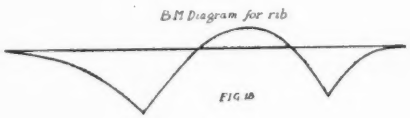
The sum of (1) and (2) gives the total intensity of stress in the spar.











In Fig. 14 the depths of the respective spars in the various machines calculated have been drawn to scale. Fig. 13 shows the cross-section of the spar. Objection might be raised to the dimensions of this cross-section, but for the purpose of comparison an alteration in this respect will not materially affect the result.

Finally there is the stress diagram for the wing cross-section. The distribution of air pressure across the plane section is that obtained on the Plane No. 13 *bis* by Eiffel.* From this distribution curve (Fig. 16) the resultant centre of pressure is obtained at a point ·31 of the chord away from the front edge. The total load per unit length of span on this plane section is taken by the two spars in the inverse ratio of their distances from the centre of pressure.

6. An Analysis of the Stress Diagrams

In looking through the figures for the intensity of stress on the various wing spars it is at once seen that the determining factor in their design is the lateral load causing bending of the spar, not that due to bending owing to the compression. This is especially the case with the large size monoplane—the spar depth necessary to give the requisite strength increasing at a very rapid rate, as will be seen from the lines for 8 and 12 in Fig. 14. This is not quite so pronounced with the monoplanes with ordinary bracing, and could probably be decreased in the king-post type by the use of a slightly increased length of the king-post. From a structural point of view the aerodynamical advantages of a monoplane of very large size would thus be outweighed by the increased weight necessary to give the required spar strength.

The question of providing adequately for the drift force acting on the wing is carefully allowed for in all modern aeroplanes. The ribs give an effective increase of width to the spar flange. Otherwise, the moment of inertia of the section would be small when taken about an axis perpendicular to the one previously considered, and were the drift, per unit length of span, of large dimensions, there would be here a serious source of plane structural weakness.

* Eiffel: *La Resistance de l'Air et l'Aviation*, 1911. Plate 16 *bis*.

7. Some Aerodynamical and General Comparisons

So long as structural considerations do not limit the size of spars or in other ways affect the design the monoplane will outclass the biplane by reason of the superiority of its lift for a given wing area, plane area section, and angle of inclination. The lift-drift ratio will, therefore, also be better, and generally the monoplane will be the more efficient type. In the large monoplane size, to obtain sufficient strength it is not only necessary to increase the spar area considerably, but also the span of the machine has to be curtailed so as to bring its size within reasonable limits. This entails a larger chord, and, therefore, a smaller aspect-ratio.

For planes of equal aspect-ratio, span, cross-section, and angle of inclination, the monoplane has about 15 per cent. more lift than the biplane for equal speeds through the air, but this advantage might be lost if the aspect-ratio had to be reduced from 7 to 4.

Referring again to the diagram of relative depths of wing spars (see Fig. 14), there is little to choose between the spars for either monoplane or biplane of the smallest size, and the decided aerodynamical advantages of the monoplane type more than point to it as the superior type for this size. The second size would appear to be equally suited whether as a monoplane or biplane. This is for a machine carrying about 1,400 to 1,500 lbs. load. For the largest size of machine the balance would seem to lie in favour of the biplane.

When the results are generally reviewed from this diagram it would appear that a limit will be first reached for monoplanes. As more loads were carried a limit would be reached with biplanes, and it would be more economical to employ the multiplane machine. This point has not yet been reached in practice. In many other ways this distribution of the types would appear to fit in well with the requirements. A small machine is essentially one that can easily be carried about and very quickly erected. There is not the same necessity for the larger size of machines to be so easily packed, and consequently there is not much advantage in a monoplane, from this point of view, in the larger sizes.

A biplane has a greater resistance than the corresponding monoplane, but the difference is not very great. What in the monoplane one gains by having no plane struts is lost by the increased size of the under-carriage members for a given diameter and arrangement of propeller.

For machines of area up to 250 or 275 square feet a monoplane is the most economical type, but from this point onward the biplane is its superior.

DISCUSSION

Mr. F. M. Green: It is unsafe to generalise, as the lecturer assumed dimensions for his constructions which were not necessarily the most favourable. When designing an aeroplane, large economies in weight could very often be effected by so altering the position of the struts and the points of attachments for the wires that the maximum bending moment was considerably reduced, and that the wing spars should be stressed as near evenly as possible.

When generalising, it is impossible to take the refinements of design into consideration, and conclusions might be seriously affected.

The lecturer has summarised his results by giving the necessary depth of spar that should be employed, keeping the flanges constant and changing the webs. While appreciating that this was done for simplicity, it could not show a fair statement of the case, as the deepest section spar was obviously the lightest for its strength. If, however, it were permissible to use a spar of the deepest section given, considerable economy would have resulted in altering the proportions of the section of the spar to withstand smaller loads.

Mr. J. Robertson Porter: With respect to stresses in monoplanes, it has occurred to me that during a sharp turn produced by rudder action, there are considerable additional stresses induced in the main transverse members due to centrifugal force. These members on the outside of the curved course receive tensional stresses, while on the inner side they

receive compression ; the heavier the surface and the more they are extended the greater the stresses. In my opinion, it is necessary to consider such stresses in combination with the ordinary bending stresses due to loading—more particularly in cases of one or two well-known monoplane types.

Mr. PIERSON : Mr. Page's method, as I understand it, of calculating stresses in spars by converting buckling force into an equivalent bending moment and summing this with the lift bending moment seems to me to be open to objection. I should prefer to use the Theorem of Three Moments to obtain the stresses—the bending and longitudinal stresses must both be calculated and then combined.

Economy of weight and head resistance can be obtained by suitably shaping struts instead of having uniform sections.

I agree with Mr. Green as to the economies to be effected by altering the spacing of struts and wire attachment points.

Mr. B. MELVILL JONES : There is a point in connection with the present discussion which might be taken into account when the relative weights of biplanes and monoplanes are under consideration : that is the influence of any difference in the drift of the two machines upon the weight that can be carried for a given propulsive force.

If the gliding angle of a machine is in the neighbourhood of 6 to 1, any reduction of drift which can be effected will allow of a corresponding increase in weight of about six times the drift reduction before the necessary propulsive force will become greater than the original value. As an instance, suppose that some improvement in a machine reduces the drift at a given speed by 20 lbs., then if 120 lbs. are added to the weight the machine will fly at the same speed with approximately the same propulsive force as was necessary before the improvement was made.

It follows from this consideration that if the drift of one of Mr. Handley Page's comparable machines is say 20 lbs. less than that of the other, 120 lbs. extra weight should be put into the wing structure of the machine with the lower drift before making a comparison of their relative advantages.

Existing experimental data appear to show that with equal loading as in Mr. Handley Page's paper the drift of a biplane will be about 20 per cent. greater than that of the corresponding monoplane, simply on account of the relative position of the two wings, and if to this be added the drift of the struts between the wings of the biplane, it would seem probable that a very considerable extra weight should be allowed to the structural parts of the wings of the monoplane before making a comparison between the two types.

Mr. B. GRAHAM WOOD : I think that the inclusion of drift wires in built-up wings, without provision for inspection or adjustment, is a source of danger, particularly where deep spars are used. Increased strength is sought by giving greater depth to the spars in the parts most highly stressed. This is all right as far as the bending moment is concerned, but the increase of stress is due chiefly to the compression imparted by the lift wires which a spar of deep section is not well adapted to resist. Where such spars are used with drift wires inside the wings, if there is no provision for their examination, these wires may work slack, and when fully stressed during flight allow the spars to bend slightly backwards. Should the spars become deformed in this way, the line of thrust would be away from the centre of the material, possibly passing outside the spar, and its strength for resisting compression due to the lift wires would be immeasurably reduced.

Too much attention is given to the bending stress and too little to the compression. I am in favour of a much more stocky section for monoplane spars.

Mr. MERVYN O'GORMAN : I think the lecturer has made a very fair comparison of monoplanes and biplanes except that in making the work occupy a reasonable space he has been obliged to equalise them—I think to an extent which is not quite warranted. He has assumed a constant wing loading of 5 lbs. per square foot for each type, while leaving the supposition that they could perform the same duty. This, however, does not accord with practice. The practical designer knows that monoplanes turn out to be more heavily loaded than biplanes carrying the same load—*e.g.*, passengers for the same duration of flight.

One more point I should like to mention. We have not had the opportunity of studying the paper before hearing it read, and it has been impossible to check in any way the actual numerical values. I do not think any member can discuss this paper as implying more than provisional assent to the actual figures we have seen passed on the screen. The amount of arithmetical work has been very large, and we owe the lecturer many thanks for the labour of doing it.

Mr. ARCHIBALD R. LOW: I had not intended to take part in the discussion, but Mr. O'Gorman's remark that the average practice of constructors indicates the probable size limits of monoplanes and biplanes brings me to my feet.

If I may refer to my note on aeroplane dimensions given at the discussion on the Army Trials, and now in print in the Journal for reference, I find in the column of constructional weights k_2 (on page 245 of the JOURNAL, October, 1912) that the Cody biplane is as heavily constructed as the Bleriot! (Laughter.) I mean of course in relation to its span and loading, just as the Forth Bridge is lighter, span and loading considered, than any twopenny-halfpenny culvert in standard steel section.

If now we increase the Bleriot until it is as large as the Cody in surface, keeping all its external dimensions geometrically similar, but altering the section of the members according to the rules given in my note, then we have quite legitimately a machine as strong as the Cody, with as large a surface, and of the same glider weight.

Sketching these to scale, we note that the landing carriage of the new machine is abnormally long-legged, to obtain the same relative strength and weight of construction and to avoid bad triangulation of the wing spars and cables.

The propeller axis and the centre of gravity are presumably capable of being adjusted to the same relative position as in the biplane. True, the lifting surfaces are higher above the centre of gravity than is usually the case in a monoplane, but not more so than the mean surface of a biplane.

Possibly a designer will arise, sufficiently free from the pressure of getting results quickly, to risk this new departure.

In the meantime, to fix the average of existing successful designs as a necessary limit seems to me a heresy of the worst sort.

Mr. F. HANDLEY PAGE: The grievous effect of making general comparisons and from these drawing sweeping conclusions has been much commented on by several of those who took part in the discussion. A word or two on this point will perhaps show you why a general comparison was necessary, and in what way the results would have been affected by the modifications suggested by several speakers.

In starting out to write this paper my object was to compare monoplane and biplane types of flying machines designed to several different specifications. In comparing ordinary machines such as exist to-day the designer will tell you that his machine is much better than one of his competitors because its total weight lifted is greater, although the actual ordinary load lifted might have been less for the same equality of performance. This was especially brought before my notice when considering the question as to whether large monoplanes would be as efficient as large biplanes, the more efficient one being that which carried the heavier load at the higher speed for equal climbing capacity. This seemed to be the case where the monoplane lifted more totally than the biplane, yet was not as efficient a machine, as the useful load carried was less owing to its heavier weight unloaded. This comparison was based on the assumption of equal stresses in both cases.

Although the comparisons have been drawn rather widely, Mr. Green will find that much the same conclusions will be arrived at if the designs were modified in the way he suggested.

Mr. Porter raised the question of additional stresses being set up in machines, when making sharp turns, owing to centrifugal force. This would hardly be so if the machine were correctly banked, as the force would then be balanced just as in the case of an ordinary banked railway track.

I am afraid that Mr. Pierson was under a misapprehension as to the way in which I calculated the stresses in the spars. I would, therefore, refer him to the details which were given in the paper as to the method of calculation. There are two stresses in the spar—the one due to the compressions caused by the angularity of the stay wires, and the

other due to the bending moment—the latter being increased owing to the spar being in compression. The bending moment is of course calculated by the use of the theorem of three moments and increased owing to the extra bending moment caused by the compressive force. The stress due to this in the spar was calculated and to this added the ordinary compressive stress in the spars. There is thus no difference between our methods. I quite agree with Mr. Pierson that considerable economy in spar weight can be effected by suitably altering the spacing of the struts.

The consideration of drift resistance outlined by Mr. Melvill Jones tends to show an increased efficiency for the monoplane, and details such as these would tend to increase the limit up to which the use of the monoplane was more economical, but Mr. Melvill Jones must remember that whilst the power required for horizontal flight can be decreased if an increase in weight is more than counterbalanced by the decrease in head-resistance, yet the weight becomes an important factor if a fast-climbing machine is required.

I quite agree with Mr. Graham Wood that the planes should be very carefully stayed with horizontal wires, but Mr. Wood in his remarks has overlooked the strengthening effect of the ribs of a plane, to which I have already referred in the paper. This increases the value of the moment of inertia about the section at right angles to that previously considered, and when the planes are suitably stayed internally in a horizontal plane there should be no fear of the plane spar bending forward or backward.

I took the same wing loading of 5 lbs. per square foot for both monoplanes and biplanes so that speakers in the discussion might not say that the wing loading being different the machine would not possess the same range of speed, climbing and lifting capacities. There is no doubt that for equal performances the monoplane could carry a bigger load per square foot than the biplane, owing to there being no interference, so that these comparisons are all in favour of the biplane rather than the monoplane. I do not think, however, if these considerations are taken into account that the conclusions will be appreciably altered. I quite agree, however, with Mr. O'Gorman, that it is a point that must not be overlooked.

Mr. Low's remarks as to the Cody and Bleriot machines are exceedingly interesting and would serve to emphasise the fact of the huge resistance of the Bleriot machine and the comparatively small one of the Cody biplane. I agree with Mr. Low that it would be "a heresy of the worst sort to fix the average of existing designs as a necessary limit." I have sought to steer clear of this evil course by judging designs on their broadest outlines, and seeking to compare the types by what is the only correct standpoint, namely, the safe working stresses in the most important members.

The CHAIRMAN: I have now to propose a very hearty vote of thanks to Mr. Handley Page for his interesting and instructive lecture. I do not feel competent, and it is not necessary, to add anything in the way of criticism. Mr. Page has taken the line of making a general comparison of types of aeroplanes from the point of view of the weight required for equal strength. For such a general comparison I think he has assumed fairly reasonable data as to loading. He has used a graphic method which is very satisfactory when the loads and their directions and points of application are exactly known, or, as in the present case, are assumed. What would perhaps also be very instructive would be to take one actual aeroplane, in which the precise position of the loaded points and joints was known, and to attempt an exact calculation of the straining actions, taking account of both direct and bending forces, and the secondary straining actions due to eccentricity of the connection of the bracing bars, and, if possible, of dynamical stresses. Then it would be possible to form a judgment as to the relative importance of the different actions and which of them were negligible. Especially in the case of bars subjected to thrust and bending, it seems that more investigation and probably more experiment is desirable.

On the proposition of Mr. Mervyn O'Gorman, a very hearty vote of thanks was accorded to Professor Unwin for his kindness in taking the chair, and the meeting terminated.

THE FIFTH MEETING of the Forty-eighth Session of the Aeronautical Society of Great Britain was held at the Royal United Service Institution, Whitehall, S.W., on Wednesday, January 29th, 1913, at 8.30 p.m. Brigadier-General D. Henderson, C.B., D.S.O., presided.

STABILITY DEVICES

By Mervyn O'Gorman

1. Devices thus spoken of are for the most part not concerned with stability of aircraft in the strict sense, they mostly pay no heed to the rotational energy stored in the aeroplane's mass, or the oscillation due thereto, or to their decrement, but, still, they strive in a vague way after one of the following :—

(a) Its safety in the air.
(b) Its staying truly on its path.
(c) Its steadiness as a gun-platform or view-platform,

and as such are worthy of review.

2. These three do not flow from one another, nor does safety follow from stability. Indeed, the three are in some measure mutually exclusive, so we will chiefly dwell on the urgent one—the first—and if needs be, let the others go. The number of inventions is so large that only a few can be considered in a paper of reasonable length.

3. **The essential speed limits :** To be in the air at all, "aeros,"* *i.e.*, aeroplanes, must move through it at a certain minimum speed, and not to break up, they must not go faster than a certain maximum. The upper limit concerns the strength factor of the construction as a rule. As regards the lower limit, no device gives safety to the flyer, unless he is protected from unwittingly reaching such limit. We touch here a cardinal feature at the outset.

4. **The slowest speed :** The minimum safe speed is the speed below which the rudder, elevator, or warp cease to have quick enough control to outvie the gustiness of the air at the time : hence this minimum is not a fixed quantity, but depends at any time on the irregularity of the wind. In any device providing against the undue falling off of speed, engine failure must be reckoned with and hence potential energy from the height and the pull of gravity must be drawn upon by the working scheme of the device. The effort derived from the organs of control falls off as the square of the air speed past them, therefore the lower limit, which is less low in proportion as the air is more unsteady, is again less low when the engine is stopped. Accordingly, though some freedom from dependence on gusts is achieved when the propeller stream is made to pass over the

Twin Propeller device :

wing flaps, as in the "two-propeller" machines of the Wright and Short types, the low limit of slow flying must not be based on the speed with engines turning but when the engines are stopped. This is the case in all aeroplanes, but is particularly so in these designs, since an appreciable strengthening of the lateral control is probably obtained with them.

5. Slow flying may be rendered more difficult by the inability of particular engines to turn slowly at partial throttle, but with this again we are not now concerned. Moreover, the slow flying which can, with skill, be effected by the process of setting the main

* I have often wished for the liberty to abbreviate the word "Aeroplanes" in this way, and since the meaning is not obscured by the shorter term, I trust it, or some other short term, may come into use.

wings "cabré," keeping them there and forcing the aeroplane forward against the very high drag* so caused (as was done at the Military Aeroplane Competition last August), is so entirely dependent on the engine, that this is not suitable for an automatic device to rely upon as yet.

6. We may conclude :—

(i.) That in examining the merits of a device, the omission or provision of a speed maintainer is of grave importance.

(ii.) That should the aeroplane give a large range between the slowest gliding speed and the fast flying speed, this adds to safety by moving the danger limits further away from each other.

(iii.) That automatic schemes must not avail themselves of this full range, but must needs keep the speed well above any of the tricky limits.

(iv.) That if the extreme limit is approached, powerful warp control and light wing loading will be useful.

7. Before going any further with the devices themselves it is useful to glance at the Curve, Fig. 1, which gives for an average calm day an indication of one-half of the problem set to us by the wind in this matter, viz., the horizontal air-speed variations measured parallel to the axis of an aeroplane when in flight. In addition to these and partially expressed in the same diagram there is the other half, the vertical pulsations which we also have to deal with and cure by sensitive pitching or otherwise. As to the latter I am unacquainted with any published diagrams or measurements which set them out independently. The indications of Fig. 1A even are approximate only, since they were taken at the end of one wing of the aeroplane and include winds other than axial up to 15° divergence. They probably give a general idea of the extent of variation of the "head-on" velocity at the various heights above the ground indicated in Fig. 1B on the day in question, but we also assume that the size of each air disturbance was large enough to include the whole wing or the whole aeroplane, though we only know of the disturbance over an area the size of a threepenny piece. Experiments are being made as to the size of disturbances at one particular locality, and when these have been made in many places some better generalisation may be possible.

8. **Vertical gusts and the shape of air disturbances :** If the vertical gust is a frequent additional disturber of the peace of flyers, and no one has made any show of a reason against this view, it is certain that we must give it more special consideration than it has yet had, and in doing so, observe that an up-current unfortunately results in a forward movement of the centre of lift of a wing curve, which is precisely what we do not want at that moment.

9. A rough pictorial notion of the shape of the air movements should, I think, help the consideration of the effectiveness of devices such as this paper is directed to, and the following, based on a note of Mr. Mallock's, though obvious when stated, is a suggestive way of putting the matter.

It is common knowledge that :

(a) Winds high up are speedy but more uniform ;

(b) Gusts, or variations of speed, occur with all winds near the ground ;

(c) The stronger the wind, the stronger the gusts, broadly speaking.

10. This state of affairs receives some explanation if compared to the flow of water by the side of a ship. Towards the stern of a ship, the water, not only near the ship's side but also a few feet out, is seen to be in eddies with vertical axes disposed in bands slightly inclined to the ship's side (Fig. 2A). The smaller eddies are near in and are the

* I adopt "drag," the word suggested by Mr. Archibald Low, in preference to the word "drift" to express the "resistance to forward motion through the air." The word drift is badly wanted in aeronautics in its own time-honoured significance, so that the actual travel of an aircraft may be compounded of the distance which it travels axially, and its *drift*, *i.e.*, the amount it drifts with the wind.

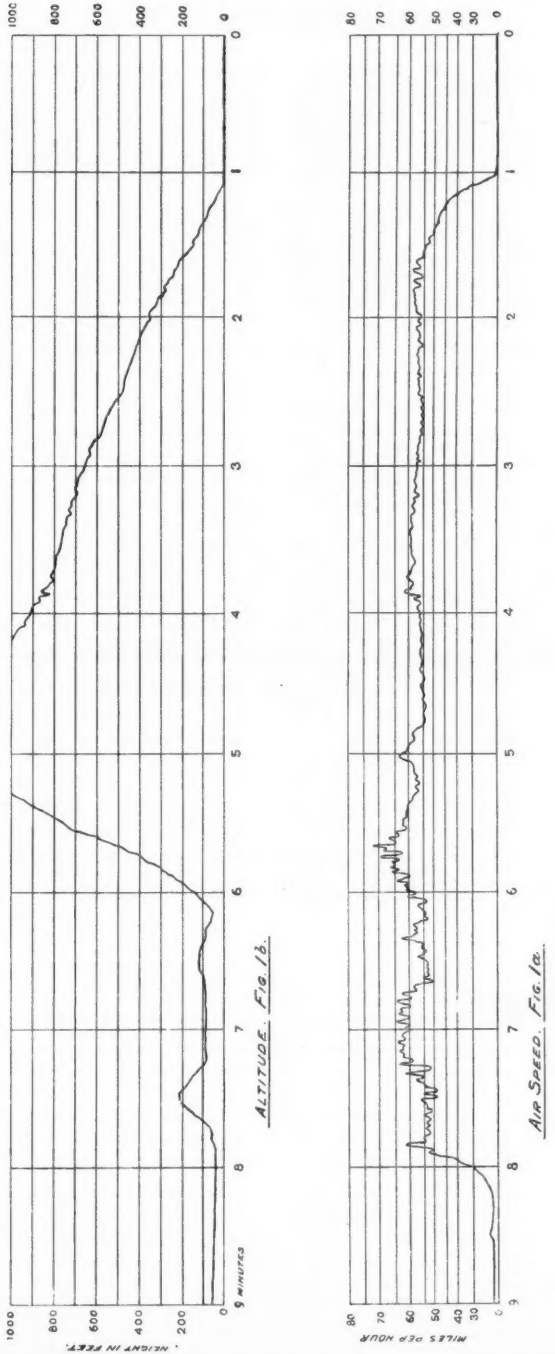
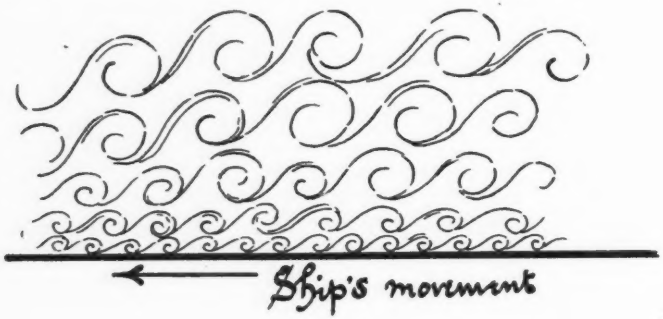


FIG. 1.—DIAGRAM SHOWING THE HORIZONTAL WIND VARIATIONS, AND A CERTAIN FRACTION OF THE VERTICAL VARIATIONS, OVER AN AEROPLANE WING WHILE IN FLIGHT

most violent—the larger are farther out—the speed of rotation diminishing in any region in proportion as it is farther out. The direction of rotation of the eddies is as if they were rolling like wheels on the ship's side. In the air the same thing happens, save that owing to the greater kinematic viscosity the belts of eddies extend farther, and that owing to the immense extent of the land the phenomenon is aggravated. A tall chimney smoking in a wide and level country gives rise to patterns which correspond very well with eddies having horizontal axes (Fig. 2B). This represents the simplified normal case.

11. Probably the large extent of land mentioned would, in the long run, so retard the air by friction that dwellers in a reasonably level country would nearly always live in a calm, such as normally occurs every night. It is the heat of the day and the different rate of heat absorption, with consequent change of buoyancy between wet and dry nodules of air which I surmise causes a mixing up of the lower or calm levels with the upper windy ones, and thus a short time after dawn we say that the wind rises, whereas the upper winds had never stopped—they are merely beginning to penetrate down to us—



FIGS. 2A AND 2B.—DIAGRAMS SHOWING RESEMBLANCE BETWEEN THE EDDIES NEAR A SHIP'S SIDE AND AIR GUSTS

putting an end to those quiet hours of flying, which we associate with the early morning. It is the equable temperature of the night which allows the skin friction between earth and air to establish a steady state unless the winds above are unusually violent.

12. The upshot of this is that vertical irregularities of air movements are to be expected, not only on high (and perhaps not so much on high with certain exceptions) but close to the ground, and since an eddy with a horizontal axis involves as much vertical as horizontal disturbance, vertical gusts occur about as freely as horizontal gusts. There is this difference between them to a flyer that, when near the earth, there is no steady vertical wind of which the gustiness is merely a percentage variation. The vertical movement is probably entered into more suddenly and may perhaps be the more difficult to circumvent for this reason. I doubt if anyone can speak positively on this point, but any record of experience would be valuable.

13. **The Wright stabiliser,* the "Doutre," and other more usual speed maintainers :** Among the known devices which purport to keep an aeroplane within its safe limits of speed, we may name : (1) the Wright Bros. automatic elevator control ; (2) the "Doutre" (see Appendix A) ; and (3) more important than either the almost universally used longitudinal Vee ; (4) the duck or "S" type aeroplane ; (5) screw propulsion ; (6) small flywheelage.

14. **The longitudinal V as a speed maintainer :** It is not usual to ascribe to the longitudinal V, open upwards between main and tail planes, the function of a speed maintainer, but that speed maintenance is one of the chief and most valuable effects of this disposition of planes has been elegantly shown by Mr. Alexander Sée in six steps, somewhat as follows :—

(a) If the speed falls off, the supply of supporting air fails, and the aeroplane comes downwards.
(b) Owing to this descent, the angle of incidence on the air is increased.
(c) The increase of angle of incidence causes the centre of *total* pressure of a Veed aeroplane to travel backwards, and gives rise to a diving couple.
(d) This dive having been started, the angle of incidence is thereby made normal again, but the travel being downwards, the machine accelerates.
(e) The speed being increased by the acceleration, the support derived from the air is increased, and the descent ceases.
(f) The descent having ceased, the angle of incidence is diminished, the centre of pressure of the whole travels forward giving rise to a "nose-up" couple, which sets the aeroplane level again.†

15. If the speed had at first increased instead of falling off as assumed at (a), the converse of all this is true. Thus, we find it helpful to restate the working of the Vee between main and tail planes by saying that an "aeroplane is guarded from risky longitudinal movement *not* when it opposes itself to any pitching, but, on the contrary, when it takes on by itself such pitching up or down as shall secure a constancy of speed "within limits."‡ We may add that the more sensitively it responds, the less time is there for the speed change to be felt, the less the amplitude of the movements and the less likely are oscillations to occur. The characteristic increase and decrease of speed of the two dangerous flight paths or phugoids (Fig. 3) (the cusped and the looped) are to be combated all along the line by a really good device.

16. **The "Tail First" or "S" type§ aeroplane as an improved speed maintainer** has for some years been more particularly studied of the makers of small models, and I know of no effect of scaling up which precludes the belief that for large craft also the maintenance of air speed automatically is improved by the "duck" form, at least in horizontal gusts.

17. The small forward plane is the first to enter the region of altered air speed, and if the gust makes the air speed fall off this plane dives in anticipation of the loss of air speed by the main wings. It thereby causes the main mass to rotate on an axis roughly parallel to and located somewhere near the main wing spars. This rotation of the main mass for a dive is effected the more quickly because it is accompanied by less air damping than the downward acceleration of the main mass itself.

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* Much on the lines of the Wright stabiliser is that described in Pat. 10,424, April 29, 1909. (Motorluftschiff.) The speed of the aeroplane is regulated by an elevator controlled by the air-pressure acting on a membrane to steer up when speed rises and down when it diminishes. The Wright plane was horizontal, however.

† Whether this swing back is accompanied by oscillations or not, is, it will be observed, entirely overlooked in this—as was indicated in para. 1 above.

‡ Alternative methods of looking at this are to be found everywhere, *e.g.*, the author's paper on Aircraft Problems. Proceedings Inst. Autom. Engineers, March 1911, p. 285, where the righting couples are calculated for various cases which have been kept simple by assumptions which are set forth.

§ I ventured in 1911 to call this "S" type after Santos Dumont, the originator, or at least the first successful flyer, with this type. "Tail-first" is a misnomer and misleading. "Canard" or Duck is legitimate.

(In the case of the "B" type or "F" type of aeroplane where the large mass is in front the damping is greater since the wing loading is necessarily less than that of the front plane of the "S" type.) I give 8 diagrams (Fig. 4) borrowed from the Aerophile of Machines of this type which have flown, and in addition there are those of Mr. Curtiss, and those who follow in his earlier footsteps, Mr. Barber's Valkyrie, the R.A.F.'s aeroplane S.E.1., the new Blériot Canard, &c. I see no objection to the type on the score of uncontrolled pitching.

18. In the opposite event of a head-on gust which increases the air speed for the moment, the front plane gets the extra lift first and quickly rises, tilting the aeroplane, and, speaking colloquially, it checks an increase of air speed of the aeroplane by setting it forth for a climb.

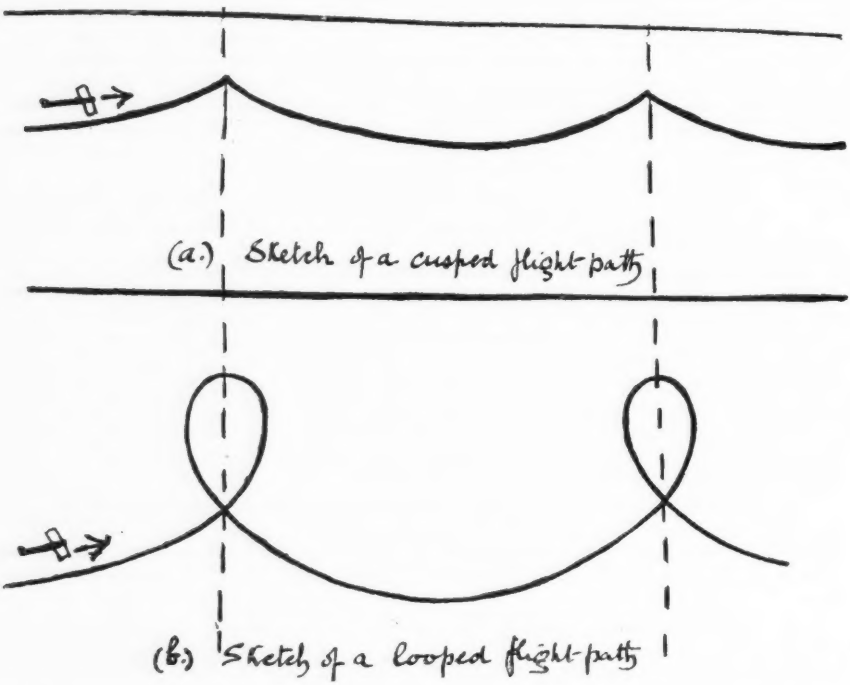


FIG. 3.—SKETCH SHOWING CUSPS IN THE PATH OF AN UNSTABLE AEROPLANE IN CALM AIR. THE LOOPED PATH IS ALSO DANGEROUS

It is probably because so much of the work of a model is effected with a small margin of power and so much gliding comes into the performance that the "duck" type has had so great a vogue with model makers. It was noticed at the Aero Show this winter that in France there is a recrudescence of the "duck" in the full-size machine just now. It may survive and I think it may even be important. If it fails it does so on other considerations than the above.

19. In paragraph 7 we have only regarded horizontal gusts and the up and down directions of travel have been treated as the only remedies for speed fluctuations. The treatment is incomplete unless we can reckon with or utilise the effect of vertical gusts and engine speed variations.

20. Some merit may be found in relation to up-gusts in the "S" type. If we refer to the diagrams of "lift and drag" of wing shapes and select the wing shape for best efficiency for the main wings we may, I think, so choose the loading and wing shape of the front plane that it will be sensitive to changes of speed but less sensitive to changes of angle of attitude. This is possible because we can select with much freedom the angle of attack of the small plane when it is in front, whereas we are restricted to narrower limits of positive angle when the small plane is behind.

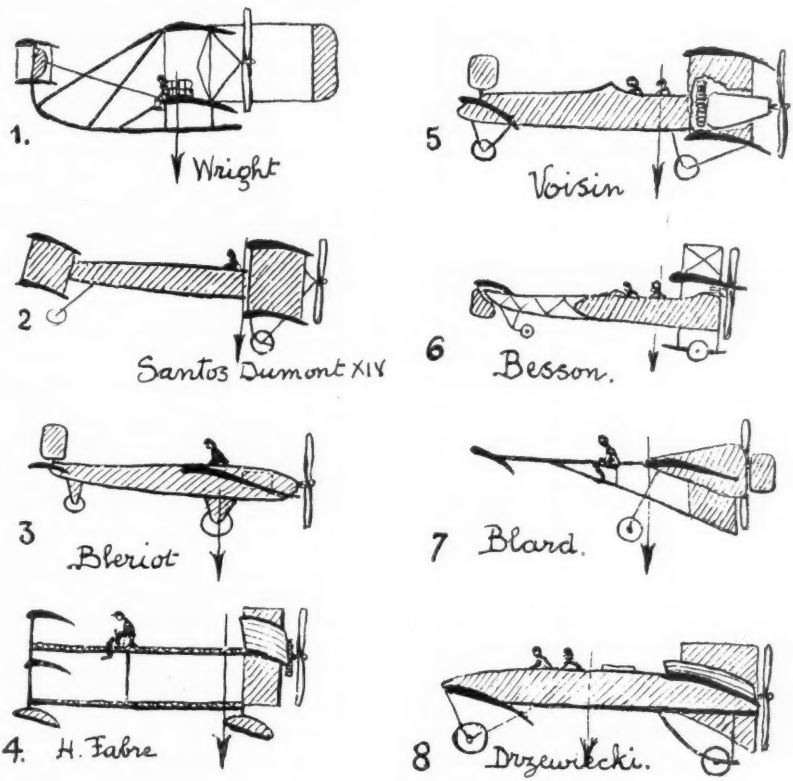


FIG. 4.—DIAGRAMS OF DUCK OR "S" TYPE AEROPLANES WITH ARROW TO SHOW THE POSITION OF CENTRE OF GRAVITY

Thus in Fig. 5A a change, not impossible if we consider up-gusts, of 9° of attitude, say from 6° to 14° for the small plane, makes far less difference of lift to it than the same change from 3° to 11° for the main wings. This, in the case of up-gusts is valuable and apparently can be got without sacrificing the normal good effect of the upturned Vee for speed maintaining.

In one example, the Drzewiecki, the curve adopted for the front plane (working at 8°) is Fig. 5A in conjunction with main wings having the characteristics of Fig. 5B, but working normally at the angle of 5°.

21. **Engine control:** No "stability" patentee who has sought constant speed by controlling the throttle from a pressure vane, or velometer, is very actual because the engine is to be regarded as unreliable and the maintenance of speed by diving must,

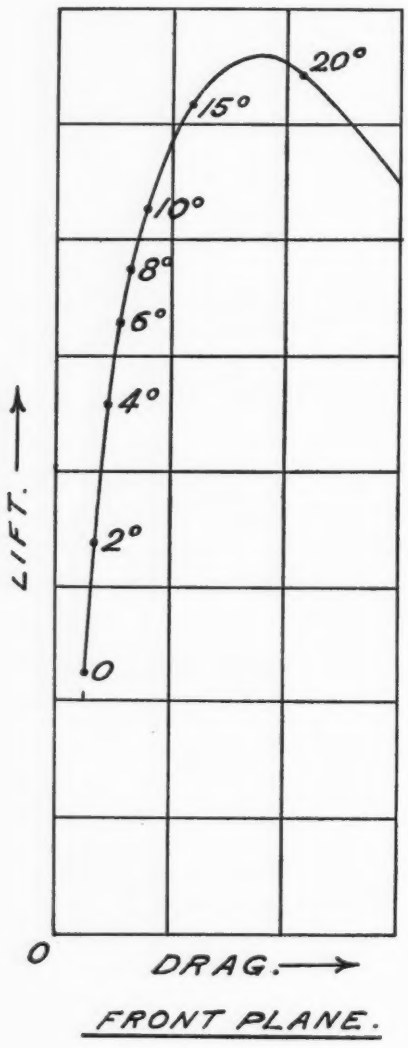


FIG. 5A

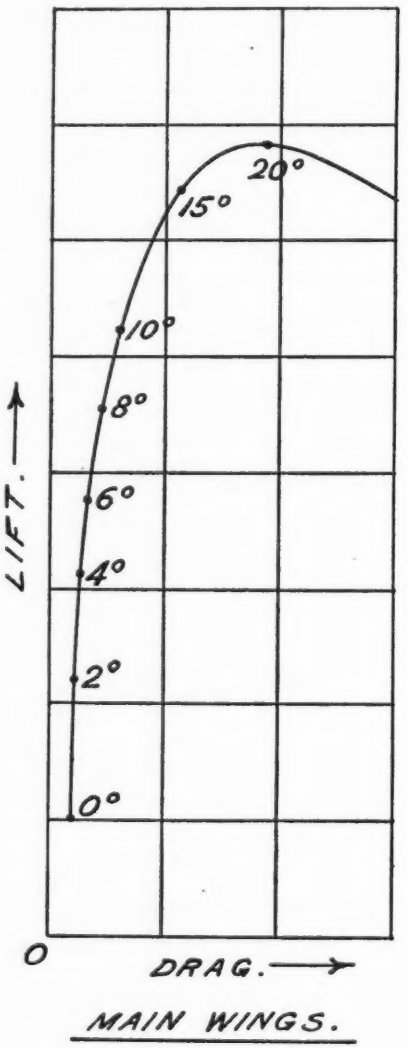


FIG. 5B

DIAGRAMS OF LIFT AND DRAG ON TWO PLANES SO CHOSEN THAT AN ANGULAR VARIATION OF ATTITUDE MAKES LESS CHANGE OF LIFT IN THE FRONT PLANE

in any case, be resorted to when the engine stops, *i.e.*, when throttle opening would be useless. Perhaps with multiple engines in the future, such may be a simple and potent cure and not the absurdity which it sounds now.

22. **Screw propulsion** has an inherent tendency, though a sluggish one, to favour the constancy of the aeroplane's air speed because a screw gives less pull during a head-on gust, and more during a following gust, as may be easily appreciated by considering

the effect of a gust either way on the propeller's slip stream, or more easily, from the common experience that a screw speeds up in a head-on gust, thus proving that the engine has been momentarily relieved of its load. The situation of the screw in front has, for this reason, an earlier steadying effect and therefore a more useful one than if placed behind. Though possibly this is insignificant in practice, now it does not follow that it cannot be made greater with special screws. Also the placing of a pair of screws, one in front of each wing, for the same reason assists slightly in the constancy of the air speed over each wing, a feature which has either escaped the observation, or at least any mention from those who utilise this arrangement. Lastly, if the line of the screw thrust is below the centre of gravity the movement of the mass under its inertia tends to equalise the speed, by causing a pitch down when the engine fails and up when its pull increases.

23. **Multi-blade screw for safety :** I cannot refrain from touching, by the way, on the terrific vibration caused by the breakage of one blade of a two-blade propeller with the consequent engine-racing. The pounding on the engine-fixing endangers the fuselage and with it any wing supports referred thereto. The multi-blade screw exercises less thrust per blade, so that the engine races less on breakage, the out-of-balance thrust is less and the out-of-balance mass is less. All these make for safety. Moreover, the blade width being less propeller flutter is less, as are the pulsations due to the blades passing a fixed object such as the wing spar and gyroscopic flutterings on yawing. For these and other reasons the Royal Aircraft Factory stuck to the four-blader when it was discountenanced in France and England generally owing to Bréguet's and other makers' early difficulties. An increased cost of a few pounds is involved, but I do not believe this system of skimping the money for aeronautical work can long be allowed to continue, when the effect of it is realised to be risky to flyers.

24. **Flywheelage or moment of inertia :** The less the flywheelage of the aeroplane round the axis parallel to the wing spar and the larger the tail the less the pitching movement will oscillate. It is a pity that very little is known or published about the moment of inertia of various aeroplanes. To give a concrete basis of comparison I mention that B.E.2 has a flywheelage of 42,000 pounds feet squared, a tail with a moment of inertia of 21,000 lbs. feet squared round the same axis and a tail area of 55 square feet [a large tail area compared to most of the usual aeroplanes].

It is not generally known that man is so constituted that his sensations in regard to the speed he is travelling at only inform him of a change of acceleration. A quick rate of change is much noticed, a slow change nearly escapes his attention. For this and other reasons the balance of advantage in favour of keeping the external weight as near an axis passing through the centre of mass as possible is a strong one, and the more strong if the righting couple is not applied automatically. It is to be observed that the force available for restoring balance is limited to that afforded by warping the wing or pulling the flap combined with operating the rudder, say as little as 30 lbs. acting at about 15 feet in certain cases for flap movement, while the time allowable for recovery may also be limited by the nearness to the ground or to an obstacle.

Quick response of the aeroplane is therefore doubly valuable both in the detection of the disturbance and in its remedying, and from this follows the utility of concentrating masses near the centre of gravity, especially as regards laterally arranged masses.

25. It has often occurred to me that, owing to the extreme urgency of getting practical results and the unfortunate and discouraging publicity which attends any originality, no one has yet attempted the slow research based upon making what might be called a symmetrical aeroplane, not because such an aeroplane is probably good, but because we could, from such an aeroplane, make departures one at a time, leaving everything else symmetrical and constant, thus disentangling the skein of causes and effects.

By symmetry I mean not only geometrical form of body, wings and tail, but the alignments on the axis of the propeller thrust on the axis of form, and placing there the C. of G.; balancing the drag so that the resistances and their moments round the C. of G. were equal, balancing fine area equivalents above and below, as well as fore and aft of the C. of G.

This still leaves the lift resultant movable fore and aft with changing attitudes, and it also allows the drags on the two wings to be unbalanced on turning and on warping. We should like to cure these but there are difficulties.

Something has been done on this latter point which belongs properly to a paper on "devices."

26. **Asymmetry of wing resistances:** The inequality of drag which exists between a flap warped to lift and a flap warped to depress is notorious, and is undesirable since it occurs usually on the wrong wing and therefore calls for a correction by ruddering, with consequent loss of speed and attention from the flyer. In May, 1911, Mr. V. Gregory brought before me two methods of meeting this: one by introducing a differential gear in the controls*, the other by cross-connecting the wires to the flaps so as to achieve equality of pull upon them. This secures an approach to balance of drag. The balance is more closely exact between the plus and minus *lift* of the two flaps, but the resistance, or drag, may for his purpose be taken as proportional to the lift and therefore balanced when the plus and minus lifts are balanced. Fig. 6 shows the cord connections which give the equivalent of a differential. They are worth the trouble of careful study.

27. If, as may prove to be the case, the future of flight depends upon the utmost refinement of balance and the minimum call upon the flyer to compensate for imperfections of the machine, a system of connections of some such kind, securing equality of drag, may yet find its way into practice, at any rate some part of the mechanical difficulty has now been ingeniously dealt with.

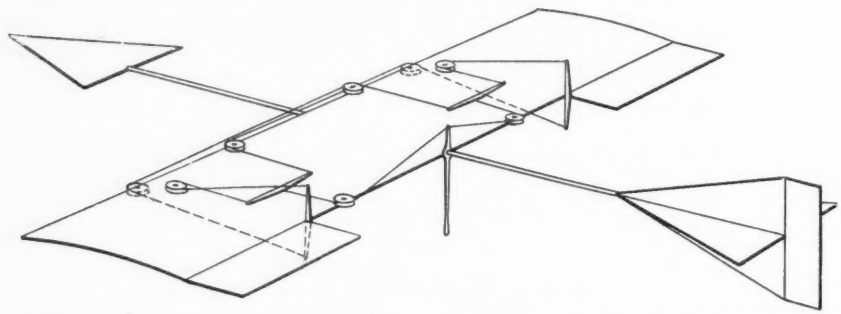


FIG. 6.—GREGORY'S DEVICE FOR SECURING SYMMETRY OF AIR RESISTANCE BETWEEN THE WINGS OF AN AEROPLANE EVEN WHEN WARPED

28. Since the aeroplane's weight is to be considered constant, the aeroplane must move so that the mean angle of incidence of the main wings is appropriate to the speed, and it would appear from this as though the angles of the flaps and wings combined must of necessity be equal and opposite, thus rendering the balance of drag impossible in this manner, or at least only instantaneous. The flaps controlled by Gregory's wiring would then be expected to become unstable or inoperative.

However, during the period when the outer wing requires the larger angle of incidence, the aeroplane's mean attitude is not the mean attitude appropriate to its weight and general speed of travel.

The wings may have an attitude different from that because we now have an extra load—the load of giving rotational acceleration to the whole aeroplane, not necessarily round its centre of gravity. [It, presumably, was not round the centre of gravity where, in old days, the flaps were not cross-connected.]

29. The period of giving rotational acceleration is the whole period of active warping—when that is completed, warping is no longer needed to give lift to the outer wing and the aeroplane remains banked if travelling straight or tends to overbank with straight wings if on a curved path.

* I have since learnt that a somewhat similar idea was evolved by Mr. Hulbert in U.S.A.

As a rule when banking is achieved, the aeroplane is moving in a circular path over the ground, and we desire that the wings should move at such an air speed that they have an equal normal reaction (or lift), fins being provided to look after the overbanking tendency. In exemplification of the effect of the Gregory device in this direction, when the warp lever of the model is fixed over to one side and exposed to fan draught, the model banks and remains banked without yawing towards what would usually be the wing of greater drag and the flaps are not unstable. If, however, the differential arrangement be put out of action and the process repeated, the model banks, but yaws round to the side of greater drag. The pivots are taking care of the fin reactions.

30. The whole business of yawing, banking and changing the course of an aeroplane is most intricate, and I am glad to see Mr. Berriman arousing interest in this question by his recent articles in *Flight*. In examining any device it is essential to consider its effect on every operation constituting a turn. If it introduces an undesirable couple, moment or force at any point it must be regarded with suspicion.

Asymmetry of Head Resistance : Many usual aeroplanes, notably monoplanes and probably waterplanes, have an excess of head resistance below the axis of symmetry of the fuselage—supposed to contain the C. of G.—or nearly, owing to the alighting chassis wheels, warping gear, &c. When the air-speed becomes high this gives rise to an important diving moment which is bad and aggravates the diving couple due to the movement of the centre of lift towards the trailing edge of the wings.

A dangerous case may occur when an aeroplane descends by diving with a down-current and emerges therefrom at the foot of the descent—an incident which we are not entitled to say shall not occur in cross-country work. If the elevator plane alone deals with this a pressure of 100 lbs. at the extremity of the tail of a well-known machine will be required to counteract the upsetting couple, apart from the effort required to "straighten out." If we cannot yet overcome the travel of the pressure resultant we can at least study symmetry of head resistance to begin with. Head resistance above the axis might even be invoked to counter the other trouble—it in fact acts in the right direction in an aeroplane with which I am familiar.

All devices arranged to keep an even keel in the face of irregularly distributed wind gusts must be put through the fire of this particular test, the test of an imaginary side-slip, and note the result. Generally they are scorched. This leads us to consider "Horizontality Maintainers."

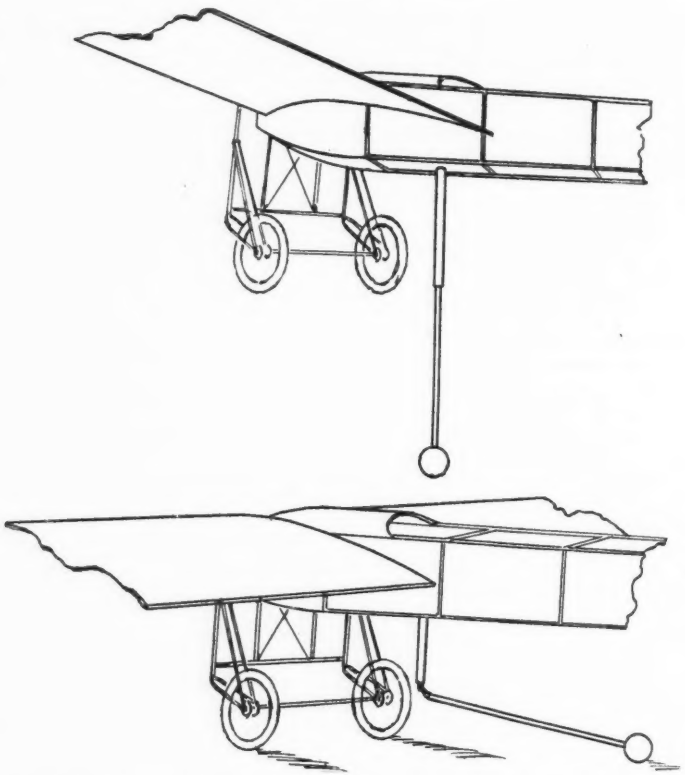
31. **Horizontality maintainers :** Many of the enthusiasts for this particular method of always countering the pull of gravity, have concluded that a hanging weight may be said to "know" better than the flyer does, the direction of the earth below them. They have accordingly called in the aid of pendulum devices.

32. **Category A. :** The majority of these are of an extreme simplicity, and some are produced in disregard of the facts :—

(i.) That when the mass of a pendulum is being accelerated it is no longer only subject to the directive force of gravity, and

(ii.) That the string of a freely suspended mass does not hang down the vertical when the point of suspension has a sideways acceleration or retardation.

33. **Category B. :** Where the effects of centripetal acceleration on turning, for example, are recognised, merit for the improved device is claimed from the fact that the mass hangs down the line of the resultant of the acceleration due to gravity and that due to centrifugal force. In certain cases good flying is certainly effected with aeroplanes in which this principle is given value—machines with an abnormally low centre of gravity intentionally so placed, like the Pischoff, &c., and most water-planes whose centre of gravity is (with reluctance by the designer), lowered owing to the mass of the floats, or when it is deliberately lowered in the hope of getting better sea worthiness, are examples of the category. In one set of flying conditions a low C. of G. undoubtedly gives an advantage, but on the whole, I think the flying is creditable to the pilot who has managed so well in spite of the device. Not the least of the incidental disabilities introduced is the fact that whenever the engine ceases to pull, or diminishes its pull, the low weight tends to elevate the aeroplane to the "nose-upwards" position, precisely that which it should not assume.



FIGS. 7 AND 8.—A LOW PENDULUM BOB CONNECTED BY A JOINTED TUBE MADE FLEXIBLE FOR ALIGHTING.

34. An example showing what I think is misplaced ingenuity is W. S. Laycock's (Fig. 7), using a very low mass rigidly connected to the aeroplane by a sliding tube device arranged to become flexible (Fig. 8), on landing.

35. Nevertheless we must beware of condemning devices which we may admit to have good points only because they are defective in other respects. The question is, can we eliminate the evil? The longitudinal pendulum, for instance, in the event of an up-gust can be made to turn the elevator down, and vice versa. It is true that in the event of the engine accelerating the same pendulum linkage will so turn the elevator as to aggravate the tendency to rise, and if the engine stops it accentuates the declivity of the fall. Both are objectionable, the latter to a serious extent. (The angle of the pendulum shaft will at the moment of engine stoppage be about 80° with the horizontal or perhaps 75° with the axis of the aeroplane on its gliding path, corresponding inevitably to a very large elevator movement if the ordinary small angles of the pendulum are to have any effect.)

36. **Renauld's bob-weight device:** As a cure Major Renauld (15th November, 1912) suggests subjecting the pendulum bob to two forces, the one always proportional to the propeller thrust and the other to the aeroplane's total head resistance. These forces are on a reduced scale so that they bear to the weight of the bob the same ratio as the real forces bear to the full weight of the aeroplane. The mimic head resistance force he gets from a small plane exposed to the wind of motion, the mimic thrust force he gets by any of the methods employed for measuring propeller thrust and duly transmitted

to the bob. Then (i.), when the forces are equal the aeroplane has constant speed and therefore a vertical pendulum is obtained which is correct. (ii.) When the flight path is inclined to the horizontal, say downwards, and when [for constant speed] the engine pull is diminished, the same gravitational acceleration acts on the aeroplane and the bob.

37. The pendulum shaft does not now remain vertical. The thrust of the propeller is less than before, the bob is pushed backwards by the head resistance plane till the pendulum shaft is at right angles to the trajectory. Thus eliminating the objection above.

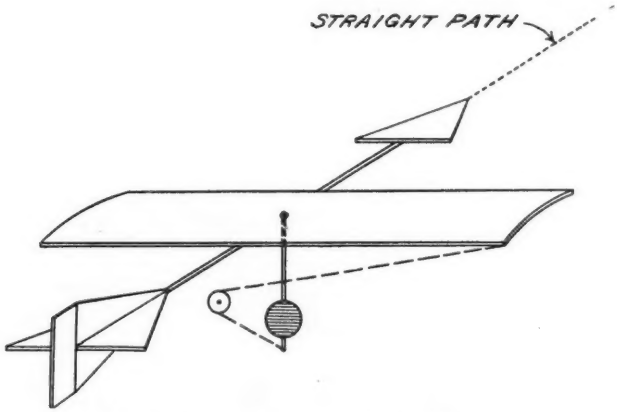


FIG. 9.—A PENDULUM CONNECTED TO WARP A WING

Such a pendulum device is only very partially "stabilising," it has nothing to do with lateral balance, but it has a tendency to correct variations in the angle of attack of the wind since we still get the corrective action for an up-gust or a down-gust.

Whether or not this or any device is "worth while" is another and a very subtle question not to be answered by the simple negative suggested by weariness of the subject.

38. **Category C. Bob-weight devices:** Perhaps the next most popular of the pendulum devices is the one which causes a centrally suspended weight to pull down directly, or through a relay, the wing flap on the side towards which the weight has moved (see Fig. 9, in which only one wing control is shown for simplicity).

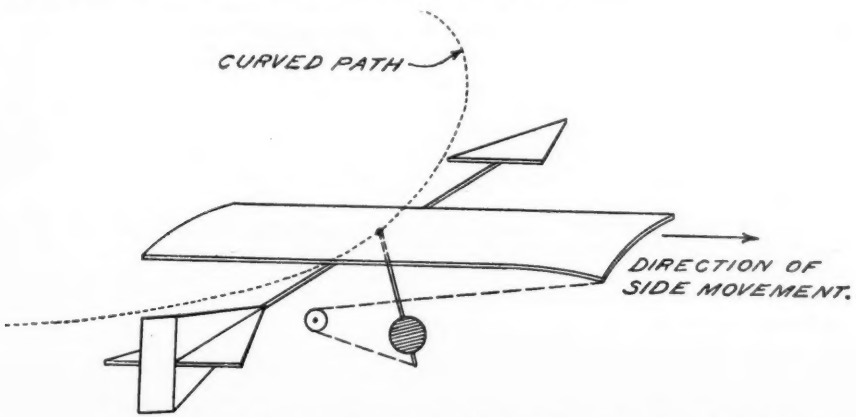


FIG. 10.—WARP-ACTUATING PENDULUM ON A CURVED PATH WITHOUT SIDE-SLIP

This gives rise to an air reaction, tending to restore the wing which is too low to its old level, and this so far is a good intention ; indeed, it is good in effect if quick enough. Moreover, it will be seen that in this case, were the aeroplane to be yawed without banking towards the left hand, the weight would fly out towards the right (Fig. 10), and so cause the right flap to be pulled down until the banking was sufficient to allow the bob-weight's line to hang more or less perpendicularly to the wing spar (Fig. 9). At this an approximation to the proper condition for a banked turn would have been achieved.

39. A criticism of this method is that it is either sluggish or calls for another device, "the fin," to enable it to do its work. Any finless aeroplane when ruddered without banking, necessarily yaws and side-slips outwards (Fig. 11), and the more the side-slipping

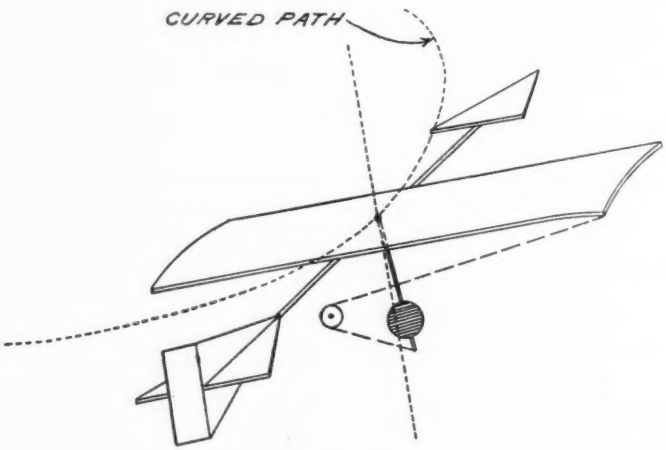


FIG. 11

movement, the less the pendulum swings out, so that the more the aeroplane side-slips, the less the device acts. In the case where the aeroplane side-slips without proper relation to the turn, *e.g.*, if it were not following a curved path, but commencing to side-slip in any sideways direction, with an increasing side velocity, the bob-weight would act as an accelerometer, *i.e.* it would lag back, due to its inertia and therefore would not introduce all that useful pull on the warp wire which banks the aeroplane in the manner for safety.

40. This last is the beginning of the typical dangerous side-slip, and failure of the device here is failure indeed. Moreover, since no change of course on to a circular path is usually effected unless the aeroplane offers some fin, or fin equivalent, it appears necessary to show that some special merit over the prompter fin method or banking by hand is obtained by pendulum control for lateral balance. No such proof is available at present, but it does not follow that no conceivable pendulum method will be of use here also.

41. **Pendulum and relay :** Gawlet's device (10184, April, 1910) is an example of an elaboration in which the pendulum is *in vacuo* and operates electric switches, which, in turn, actuate the elevator and warp through a compressed air device. No mention is made of how to overcome the difficulty that the same correction is given to the elevator in the two cases :

(1) When the aeroplane engine stops pulling and gives loss of air speed, and
(2) When a gust strikes the aeroplane and slows it as a whole, but giving increased air speed ;

while these two occurrences require opposite elevator correction for speed maintenance.

Laterally similar conundrums are introduced since similar pendulum action results from side movement due respectively to a side gust and due to a side-slip, although lateral control movements desirable in the two events are opposite to one another.

42. Such devices as Gawlet's if they were worked out would not be devoid of interest even if they were wrong. There is a vast gulf fixed between the theory of a mechanism which tells the controls what to do, and the production of that mechanism within the weight limits needed for aero purposes. The evolution of electric, pneumatic, or mechanical relay devices for aeroplanes are exceedingly difficult problems, and may well be utilised in the near future. It is unfortunately usual for the inventor to set out a theory and stop there—after the easy part is done. The theory of a watch is quite simple, it has taken centuries to evolve the reliable thing we use, hence real workers in this field are as welcome as they are rare.

43. Wendtland (8326, April 4, 1910) balances laterally by causing a pendulum to deflect a blast of air under one wing or under the other. This, of course, fails when the engine fails.

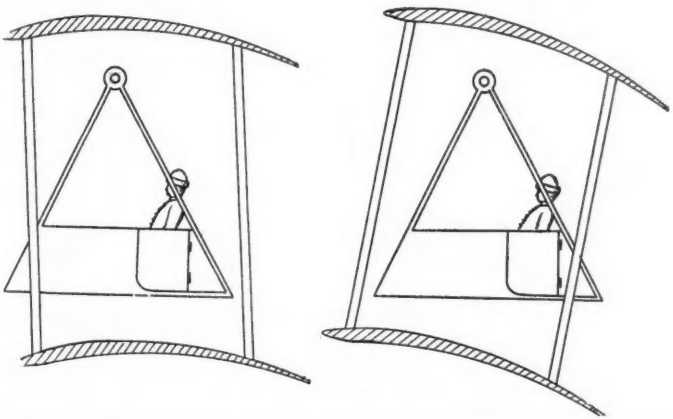


FIG. 12.—AN EXAMPLE OF A FREQUENTLY INVENTED PENDULUM DEVICE. (SCHMITT'S)

44. **Pendulum without relay :** Schmitt's scheme is a curious example of the opposite kind where the sensitive relay and its troubles are evaded by introducing others incidental to the hingeing of all the fundamental parts so that they shall constitute a heavy pendulum (Fig. 12). His patent (11,355, May, 1909) claims that it entitles him to dispense with the tail. He hangs the weights of pilot engine, &c., in a frame below a hinge which is parallel to the main wing spar and arranges that when the wings are given a greater angle of incidence by the flyer the movement of the centre of pressure (which he mistakenly assumes to be backwards under these circumstances) is attended by such a movement backwards of the chief weights that these remain always underneath the centre of pressure, and thereby the upsetting couple which the tail corrects for is not introduced. He forgets that the wind moves and varies the centre of lift independently of his intentions and very quickly, and he is misinformed as to the direction of movement of the C.P. of cambered aerofoils.

This type of device has benefited the patent offices of France, England and U.S.A. in various forms, and it seems a pity the money should not have been spent on aviation.

45. Planes Ltd. and Thompson (April 19, 1910) suspend the car flexibly from the wings and the adjustments of the planes for steering and balancing are effected by movement of the car. This car movement is also controlled by a lever.

46. Mitchell (4249, Feb. 20, 1911) causes his suspended car to bend down two balancing flaps which extend beyond the wing tips. The flaps are cross-connected.

47. Adam and Stamkort (4408, Feb. 21, 1911) balance an aeroplane by running electrically a carriage of considerable weight, and bearing two accumulators and motors, the pendulum consists of a mercury switch in which the liquid flows over the appropriate contacts.

48. **Dulier's advancing wings as maintainers of horizontality :** Colonel Dulier desires by the process of advancing the wing of his "Aerocar," when steering combined with warping the tail, to secure that it shall maintain perfect horizontability on the turn, both as regards the lateral and longitudinal axis.

His scheme is based on the behaviour of some birds, amongst them certain pigeons. Such a bird's method, he says, for turning sharply to the left, is, contrary to the views of aeroplanists, to advance or extend the left wing, thus bringing its centre of pressure forward of the main weight, then both wings are raised, the inner or left wing's trailing edge being progressively warped, beginning at the extreme tip which is thus the fulcrum or pivot of the turn.

These first movements tend to put the bird "cabré" and a correcting movement is therefore made with the right side of the tail which is accordingly advanced or extended and also warped for lift.

49 The device which he offers as an improvement on present means is given in Fig. 13 without clear explanation of its utilisation. It is fortunate that inventors have

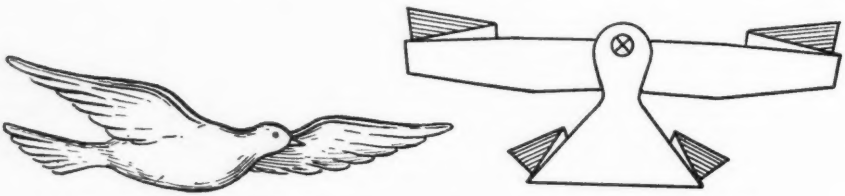


FIG. 13.—COL. DULIER'S ADVANCING WING DEVICE FOR TURNING HORIZONTALLY

the divine afflatus which enables them to persevere in their apparently unpromising ideas, otherwise we should certainly not be flying as we are to-day. If Colonel Dulier's bird observations are correct, however, they have this of interest, that just as little birds paddle hard and then proceed like a projectile with closed wings abandoning all support from the air for a spell, so certain other birds, on turning, say, to the left, abandon most of the support the air would give and use their wings and tail to produce a large fin effect. mostly top fin.

50. The left wing makes a large top fin forward and a front rudder (Fig. 31), the right wing a large top fin central, thus taking the side air pressure, while the tail is used to compensate for the disturbance of general attitude and becomes the rear fin by the act of being warped.

51. Colonel Dulier says that in spite of all these movements the bird is banked inwards. It is quite conceivable that such a fin disposition with a balance of forward fin area would make for an extremely rapid turn once the slightest commencement of a turn had been made.

Under these circumstances the right wing will get so much air velocity that it will give an amount of support equal to or greater than that of the left wing when put forward.

If the observation is correct the turn will be amazingly rapid and will give the defenceless pigeon a chance of escape from its foes, much as a hare doubles and a rabbit dodges.

52. The scheme is not necessarily suitable for imitation in mechanical aircraft, though the speedy and defenceless scouter aeroplane might welcome the ability to perform such a manœuvre in war. Horizontality, however, is not secured. Colonel Dulier, in common with many inventors, appears not to realise that the wings have not even as much as the pendulum any "knowledge" of the vertical, yet if we are to remain horizontal this knowledge must be imported from somewhere. I am not clear whether

he has overlooked the fact that slipping in the sense of moving in a direction other than axial with the aeroplane is a necessary incident to aeroplane flight on turning, since a new direction of motion cannot be obtained without destroying momentum in the old direction by doing work on the air at the side of the craft or under it. At any rate, he does not draw attention to the one feature of his observations which seems to be most interesting, the rapidity of turning secured for the pigeon.

53. **Horizontality maintainers (lateral):** Equalising the wing pressures. Countless persons have thought that if provision were made to prevent the total pressure under one wing from exceeding that under the other, the aeroplane would always remain laterally in the same horizontal position as it started from. The moment we consider the side-slip involved by change of course it becomes clear that perfect balance of fin area above and below some centre of lateral pressure would be necessary also, always supposing horizontality to be desirable.

54. There are large numbers of persons in favour of equalising the wing pressures if we may judge by the actual constructions in use. Thus Breguet's and Gaudron's springy wing ribs, R.E.P.'s (patent 10,575, 1909), spring-supported wing span, &c. We may include in this the standard scheme of balancing by cross-connecting the warps, &c., though I do not accuse any of these of concentrating their wishes on horizontality.

55. Ramel and Bille (28,778, December 11, 1909) propose to equalise wing pressures by allowing the air to spill out of the wing which has most lifting pressure by letting it tilt up, thereby bringing the wing which has least lifting pressure to tilt down, while the main mass of the flyer and motor and fuselage remain unrotated save through the indirect action of springs which connect the wings to the main mass (Fig. 14). Here we

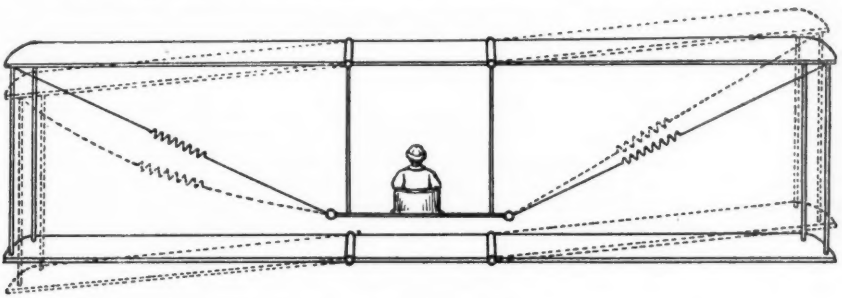


FIG. 14.—WINGS ARRANGED TO TILT LATERALLY TO EQUALISE THEIR AIR PRESSURE

have a vague attempt to keep the man's seat more horizontal so that there is an element of the pendulum in the device. That he should be safer thus does not appear. This at least is sure, that with the pressure variations which arise in practice large angles of tilt will be found to occur, and the effect will be most terrifying to the man of ordinary training unless some other method of pressure equalisation is intended to be superposed.

56. **An effect of equalising wing pressures:** There is one matter in relation to the equalising of wing pressure which must on no account be lost sight of whether we use springs, cross-connected warps, or pneumatic equalisers, &c., and that is, the more perfect the equalising the more completely the effect of the dihedral angle is wiped out, since the dihedral angle only acts by reason of the difference of pressure established under a descending and a rising wing.

Accordingly a dihedral angle has none of its usually recognised effect if the cross-connection of the warps of the two wings is frictionless, if the warp be sufficiently ample and if it be not controlled by the springiness of the warped spar or otherwise. This has been experimentally tried on BE2. With cross-connected flaps and rigid wings as in the Farman aeroplanes this loss of dihedral effect does not hold to anything like the same extent.

57. It is doubtful if equalisation is ever entirely secured and therefore in criticising "horizontality maintainers" lateral, rolling disturbances are to be looked for in spite of attempts in this direction. Some of the disturbing causes apart from fin pressures are :—

(1) From the effect of changing the course, as for example the swing of the weight when the centre of gravity is placed a trifle low.

(2) From the flywheel effect of the aeroplane as a whole by the swing due to recovering from an intentional roll or yaw displacement.

(3) From difference of wing speed on a turn banked or otherwise.

(4) From minor causes of disturbance including the gyroscopic couple on elevating or yawing, from the movements of the flyers, or from engine reaction on starting or stopping, &c.

Of these the first two are the most important usually.

58. **Fin disposition :** Not the slightest importance can attach to fins except in the case of side-slips, and side-gusts. Moreover the effect on fins of vertical gusts when the aeroplane is banked reduces itself eventually to a side-gust from the point of view of the aeroplane.

Although I am not to deal with it, it is right to say before concluding that by far the most important feature of an aeroplane of supposed average performance in other respects is its fin disposition, and probably next its weight distribution. This subject launches us straight into the rigid dynamics of de Bothezat, Bryan, Harper, Greenhill and others, or alternatively into the method of Lanchester, who obtains conclusions which the mathematicians accept, though he adopts a line which is sometimes captivating by its ingenuity and sometimes a process of skipping the links of thought in a manner baffling to the less skilled reader. A translation by Lodge or Silvanus Thompson of his work would be of priceless use to English aeronautics.

59. After Mr. Harper's excellent, though difficult, paper before the Aeronautical Society this year, I will not venture, save by alluding to it, anywhere near this subject. He was entirely concerned with air which was either still, or at least straight moving and unaccelerated, which is the same thing in this context, and in his discussion, once the disturbance of equilibrium had been given to the aeroplane it had still air in which to resume its proper seat.

60. Other simplifications and premises such as the absence of any movement of the centre of pressure on a wing with variations of attitude were made, and even in these circumstances the mathematical treatment became sufficiently abstruse. What it would have been with true aerofoil conditions if the ambient air were supposed to be horizontally gusty according to a complex law is difficult to imagine, but in the event of there being not only horizontal, but also vertical gusts, of the kind indicated in paragraph 10, the treatment would doubtless be beyond human ken to-day. Yet this is the practical problem we are out to solve. For the present Bryan's simplifications must be of great use to us especially as a guide to thought—just as the hydro-aeroplane must be first studied in the simplified conditions of calm water before it is modified to suit a rough sea.

Horizontality maintenence by flaps : Wildeblood's invention (11,334, May 7, 1910) is an excellent example of the difficulty so recurrent in flying work that what is a safeguard against disturbance by side-gusts provides a danger in the event of side-slip.

The idea is original. The flaps face inwards and hinge on their outer edges when a side gust comes as shown in Fig. 15, tending to raise the left wing it moves ineffectually over the left flap and meeting the right flap raises it and so puts it into an attitude to give a strong lift. By suitable shaping, the upward pressure under the right flap is equal to the extra lift under the left wing, and balance is maintained.

If, however, side-slip occurs towards the left side the right flap is raised and catches the air as before, thereby increasing the lateral slope. Mr. Wildeblood's models are so very successful that I should like to know more about them than is disclosed by his patent before pronouncing on them.

Model tests : Model gliders, on which an engine failure and consequent stalling is not to be feared with its resultant side-slip, may quite well be expected to perform with this arrangement for the large majority of flights, particularly since voluntary steering with its attendant side-slipping and unbalanced lifts to the wings is also eliminated.

Nevertheless, Mr. Wildeblood can probably show that provision has been made which avoids the anti-banking effect on side-slipping. If the spiral nose-dive is claimed as one of the steps towards recovery of flight speed and eventual resumption of horizontal flight with the device, this may under some circumstances be admitted, but it implies that which does not always occur in real life, namely, that there is always plenty of space below to give the time for recovery.

Unfortunately with models intended to show the merits of particular devices, though the model may succeed it is not always due to the device displayed but to other incidents which are not made so obvious in the demonstration—fin areas, upturned wing tips, stiff movement of balancing flaps, abnormally light loading in relation to wind characteristics, unusual head resistance, or head resistance distribution, &c., &c. Therefore deductions from successful models must be made with great circumspection, and indeed I am strongly in favour of the construction of full-size "models" sent up without pilot over some large piece of water for the study of safety dodges.

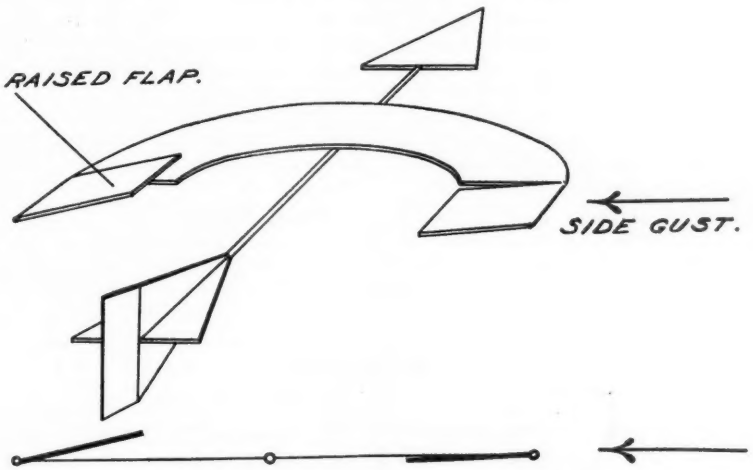


FIG. 15.—WILDEBLOOD'S ARRANGEMENT OF BALANCING FLAPS ; THE RETREATING WING ACTS AS A DIHEDRAL BETWEEN WINGS

61. **Gyroscopes :** This subject was dealt with at length by Mr. T. W. K. Clarke, at present on the staff of the R.A.F., in a recent paper before the Society. It is not suitable for a corner in a long paper. I will only touch on it briefly. A large gyroscope rotating [not as the Gnome usually does axially with the aeroplane, but running as if it were a wheel running forward] will tend to maintain horizontality, against lateral rolling, because it will tend to advance the wing which is lowered—this tendency if encouraged will give it extra lift. This applies to both wings and so far we have the germ of a device. It has no effect on pitching. If however we try to bank it will oppose itself thereto, a matter of no great moment since we can easily overpower it. The chief objection would seem to be that it will tend to maintain any banked attitude once it has been reached, including dangerous banks on to which we may be thrown by a strong gust.

62. There are two matters of interest in connection with gyroscopes of the dimensions of the 100 Gnome engine : one is to know what is the order of magnitude of the gyrostatic couple ; the other is to realise that the gyrostatic couple vanishes as soon as the aeroplane begins to yield at the rate called for by the precession.

This second fact is almost always ignored by the vague inventor, of whom there are so many, and who count on a continuance of the effect until the righting is achieved.

For all this, it is useful to have the results of calculation and experiments which were made for a different purpose, and which show the disturbing effect of a 100 Gnome engine and propeller, together under legitimate but severe conditions of quick diving and quick turning.

63. This work showed that :—

(a) The gyrostatic effect of the propeller alone is a trifle greater than that of the Gnome engine which drives it, say as 184 lbs. feet is to 140 lbs. feet when the rate of diving or turning is one-third of a radian per second.

(b) It is unnecessary to make the two effects additive, since by the simple expedient of gearing them in opposite directions the couple can be reduced to insignificant dimensions.

(c) The gyro effect of even 100-H.P. Gnome is not nearly as important as often supposed, and can be countered by elevator and warp movements of small dimensions even when turns and dips of considerable sharpness are executed.

(d) The developing of a large gyro couple can be caused only by trick flying of a kind in any case to be discountenanced.

(e) The total gyro effect of engine and propeller together in the above case is 324 lbs. feet for turning by ruddering one revolution in 20 seconds.

(f) The total gyro effect of engine and propeller is 330 lbs. feet for turning down by elevator at the fast rate which would relieve the pilot of any sensation of weight on his seat in a 60 m.p.h. aeroplane.

Even these maximum couples are well within the controls. They give just the same sensation and call for the same correction as gusts of moderate force, for which the flyer must in any case be prepared.

General methods : *Joussaint and Lepère*, having evolved a velometer (July, 1912) using a Pitot tube, propose to employ the diaphragm of the recorder to control the elevator through a relay. This would put their device into the class " Speed maintainers," but they combine with it a lateral balance apparatus. They pierce a number of holes in the upper and lower parts of the wings, fit these holes with tubes carrying the algebraic

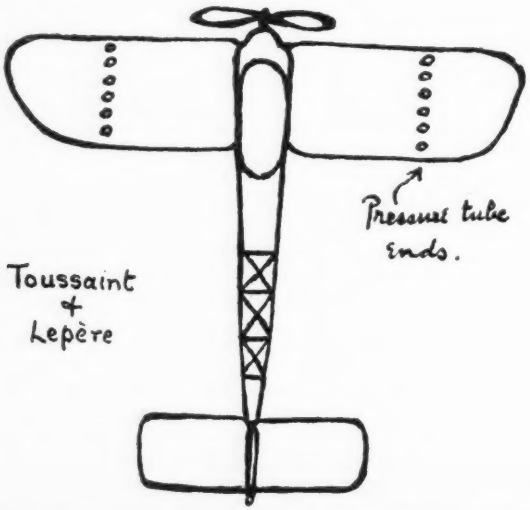


FIG. 16.—THE HOLES FOR PRESSURE MEASUREMENT IN JOUSSAINT'S DEVICE

totalised pressure difference between one wing and the other to a diaphragm which actuates a lever which in turn operates electric relays (or alternating pneumatic relays) to warp the wings. The elaboration is very great and it does not appear clearly that the simpler methods of balancing wing pressure, &c., are not at least equally good—at any rate, what the authors achieve is not "the automatic stabilisation" indicated in the title given to the description.

Anticipating the disturbance: I venture with some diffidence upon a device of my own relating to soaring but bearing on this subject. Whatever disturbance an aeroplane is suffering from, its rectification inevitably takes time, during which the machine covers an amount of space which may cause a critical situation. Accordingly therefore we must seek for prevention rather than cure. The human operation of the controls to outvie the effect of gusts is never more than a cure. Man cannot feel the velocity of his movements, nor even an acceleration, but he is extraordinarily sensitive to a change of acceleration. Witness the exaggerated accounts of the movements due to earthquakes which can be proved to have been less than a millimetre in amplitude, or his power of detecting the vibration in his house due to a passing traction engine. It is to this sensitiveness that human flight is in large measure due. So long as man control dominates, a concentration of the mass to allow this sensitiveness to operate is required, while the conditions of aeroplane building inevitably distribute the masses a good deal. On my earliest passenger flights I noticed with surprise the distinctness of the double blow produced by a gust first on the front plane and then on the back plane, and from that concluded that a forward feeler would anticipate the truth. This was three years ago. To make this anticipation quantitative it occurred to me that the best forecast of the probable effect of the gust would be conveyed by a measure of its acceleration. [Note, *not* the acceleration of the aeroplane in relation to the air which it is in, but of the gust.] Any air-accelerometer would do, and as priority of thought is interesting at least to the inventor I mentioned the whole matter in detail to Captain Fulton, R.A., about twenty months ago. A simple form consists of a light-plate of good aspect-ratio near which hangs a mass (duly sheltered from the wind). The amount of separation occurring between the vane and the bob measures the air acceleration. One feeler is placed forward of each wing. A sort of calliper which measures this separation is made to control a pneumatic motor which alters the curvature of the appropriate wing negatively for a positive acceleration and vice versa. If both feelers get a head-on gust both act. It will be observed that as there is pre-warning of the movement of the centre of pressure this can also be used to inflect the tail so as to counteract the upsetting moment due to this movement of the centre of pressure.

A vertical up-gust has the effect of separating the vane and bob as if it was an acceleration, and so long as the vertical gust lasts the aeroplane needs less lift and the flattening out of the wings is therefore appropriate.

A peculiar feature of the device is that it utilises the one and I believe only air-difference which exists between a side-gust and a side-slip, viz.: that the gust strikes first one wing and then the other, whereas a side-slip strikes both simultaneously. Thus on a side-slip occurring both feelers are equally affected so long as there is side acceleration and no out-of-balance warping is introduced to aggravate the side-slip. Side-slip is cured by the action of the top fin which should provide against it.

The device by anticipating the strength of the gust eliminates the objection to a top fin which is that it forms a target for a gust.

Throughout all this it is well to remember that a gust is not a gust as far as the aeroplane is concerned as soon as the aeroplane as a whole has taken up the speed and direction which the gust seeks to impose. Accordingly what appears to be a gust to a fixed observer on a tower ceases to be so to the aeroplane immersed in it. This is the foundation of the use of the air-accelerometer as a feeler on an aeroplane. An "invention" of this sort is quite valueless until some kind person works it out in detail.

Limitation of elevator movement: Mr. A. Sée has strongly advocated protecting the flyer from his own rashness in using his elevator too fiercely for descent. Imbued with the fact that a much-depressed elevator gives an inverted longitudinal Vee, he suggests either a stop presumably such that the inverted Vee is not reached; or a spring

giving by its stiffness warning to the flyer that he has reached this point; or a *front* elevator convex downwards; or the automatic operation of the elevator (like the Doutre).

The difficulty of accepting these views outright is shown by the fact that the flyer must be allowed to determine his course, that is to say, in the case of an eddy like that shown in Fig. 2 when the aeroplane may be in the up-current side, and the flyer has, as he may have, good reason not to rise, say in the presence of an enemy (to avoid appearing over the horizon), or because another aircraft is over him, or because he in fact must at that moment alight, he needs unhampered control of the utmost elevator movement. This is a case for tentative trials as to how far such restriction can be tolerated.

In conclusion my apologies are due to the countless inventors whose devices I have not mentioned; I only hope they may be here with diagrams and models to fill, in some measure, the lacunæ which I am all too conscious of having left.

APPENDIX A

Doutre stabiliser, 1912 model, weighs 44 lbs. The air-speed causes a pressure on a plate P which then compresses a spring R^1 till the plate shaft rests on an abutment for normal travelling speed. If the speed falls off the spring tends to send back the plate and this opens one valve of the pneumatic motor in the direction for lowering the elevator.

In addition a floating mass M slides over the shaft along the line of flight, being kept centred by a spring on each side. These springs are stiff enough not to be appreciably affected by the fractional weight of M if the aeroplane travels down a slope, but they allow M to travel if there is a more appreciable acceleration of the aeroplane.

It is clear that the valve of the pneumatic motor is controlled by the resultant movement of the plate and mass. Example, if the airspeed falls off the plate takes the position shown, this pushes the mass forward as shown and opens the valve. Had there been a strong acceleration in the direction opposed to the wind the mass M would not have come forward, and therefore the elevator would not have been depressed as shown.

In the 1913 pattern the mass is arranged to act vertically instead of horizontally, being connected to the same mechanism by means of a bell-crank.

It is unfortunate that when the aeroplane slopes down a glide, say of 1 in 6, the mass *tends* to move as if the aeroplane were suffering from a retardation, with a force equal to one-sixth of its weight. To this extent there is a tendency to accentuate a dive until the airspeed on the plate P is high enough to correct this tendency, aided by the lag of the mass due to any acceleration downwards in excess of one-sixth of gravity.

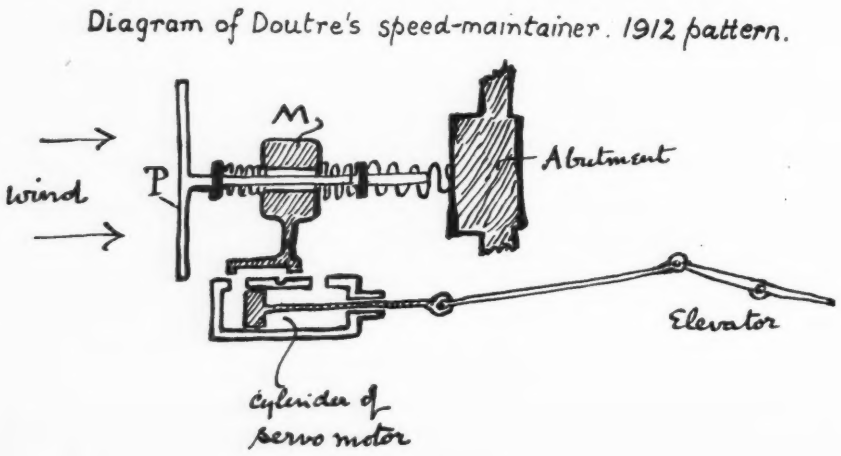


FIG. 17

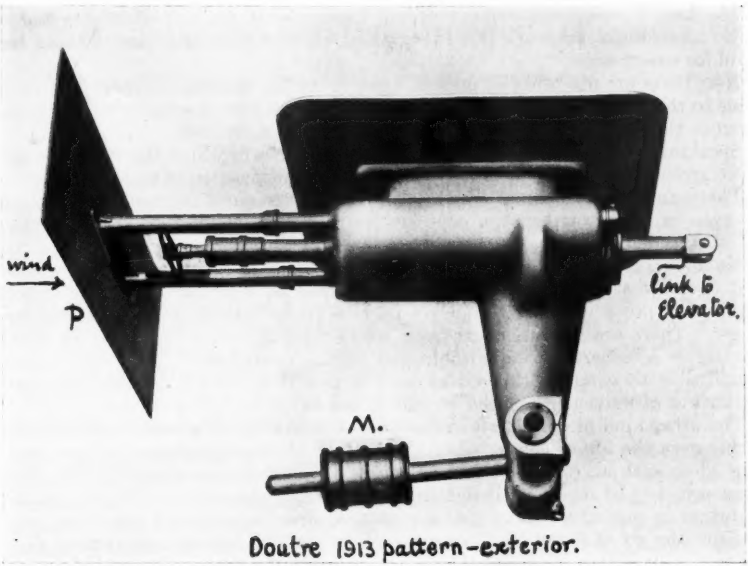


FIG. 18

At the conclusion of Mr. O'Gorman's paper, Mr. Busk, of the Royal Aircraft Factory, exhibited the instrument on which were obtained the curves in Fig. 1, and which gave in addition a record of the deflection of the aeroplane from a level keel, and of the control movements consequent thereon. The name "ripometer" has been given to this instrument. Mr. J. W. Dunne then read a communication to the Society on the theory of his automatic-stability aeroplane (reproduced herein), and Mr. A. P. Thurston showed some slides of Sir Hiram Maxim's experimental apparatus in his stability experiments of 1894.

The CHAIRMAN: I am afraid that at this late hour one cannot expect you to discuss the extremely interesting papers we have just listened to. We hope, however, to arrange for a discussion on Stability shortly, with special reference to what we have just heard, which has at any rate made it quite clear that there is still plenty of scope for inventive genius in the matter of aeronautics.

First of all I wish to suggest some words for definition by the Technical Terms Committee of this Society. This word stability, for instance, is used with several quite different meanings, none of which are absolutely connoted by the ordinary meaning of the word. By some people, stability is used as a synonym for balance, others appear to apply it to mere stiffness, and in the popular mind it is associated with any device which will lessen the risk of a fall except through absolute breakage. I might mention in passing another word which is persistently misused: that is efficiency, which is usually applied to what is only one factor of real efficiency.

Taking stability in the meaning with which it has been used to-night, the opinion seems to be forced on one that most inventors have aimed at perfection rather than at improvement, and it seems to me that in other mechanical contrivances, the inventions which have been most successful have been very much in the nature of improvements, and sometimes very small improvements, and that it is to the cumulative effect of many inventions and seldom to the effect of a single effort to attain perfection that such advancement is due.

Speaking, not as an expert, but as an enthusiast, I would venture to suggest that there are two different lines along which improvements and stability might well be sought.

The first is such improvement as will lessen the strain and effort imposed on the flyer so as to make his work less exhausting, while at the same time leaving him full control for emergencies.

Now there are machines at present existing which, in calm weather, give very little trouble to the pilot, but in gusty weather some of those very machines, although no more dangerous than others, do cause the pilot considerable difficulty.

Speaking under correction, I imagine that machines in which the wings are designed so as to give a certain amount of self-warping would be included in this class.

There are other machines which, although they require continual attention of the pilot even in calm weather, are comparatively easy to handle, even when exposed to gusts of considerable force.

No doubt, many who are present are acquainted with machines of both these types, and it does not seem impossible to devise a system by which an aeroplane may be left to itself very much in still air, and yet may be comparatively easy to control in gusty weather. There are models in existence which when properly adjusted, fly very fairly in a calm or a moderate wind without any human control whatever, and it should not be impossible to combine this virtue with a powerful control for the correction of irregularities of movement caused by strong winds.

The other kind of stability which seems most worthy of investigation is that which may preserve the life of a flyer when the movement of an aeroplane is from any cause disturbed to such an extent that the controls are unable to remedy it. The discovery of some principle by which a self-righting couple would be established which would restore equilibrium in case of a serious side slip or nose dive or backward fall of an aeroplane, would put the art of flying on a new basis altogether. I am inclined to think that until some such contrivance is produced, there is no hope of aeroplane flying becoming either a popular sport or a commercial possibility; flying will be confined, as it practically is now, to those to whom it is either a duty or a means of livelihood, either by instruction or exhibition.

I now ask you to express your appreciation of the trouble which Mr. O'Gorman has taken in the compilation and reading of his interesting paper, and of Mr. Dunne's careful explanation of his theories. I am sure you will wish to say a good deal at the adjourned discussion, on the many points raised.

A hearty vote of thanks to the Chairman terminated the meeting.

THE THEORY OF THE DUNNE AEROPLANE

A Communication to the Aeronautical Society of Great Britain,
By J. W. Dunne, A.F.Aë.S.

(*Read at Meeting on 29th January*, 1913)

This small addition to the evening's programme has been made possible by the courtesy of Mr. Mervyn O'Gorman, who has cut out a portion of his lecture in order to make room for me. You, as scientific people, will realise that this is just about as generous a thing as a man can do, and I can assure Mr. O'Gorman that I am proportionately grateful.

The title of Mr. O'Gorman's lecture has suggested to me that perhaps after all the simplest and most readily comprehensible way of describing this machine is to present it in its aspect of a combination of a number of stability devices. This lecture will therefore be more qualitative than quantitative.

The first person to try the effect of negative wing tips was Professor Marey—he tried it on a double sheet of note-paper, weighted as a glider.

The first person to propose the use of backward-sloping wings was Mouillard. In advocating this plan-form he does not appear to have had stability in his mind at all, nor did he propose a permanent slope-back. His object seems to have been simply to provide a means for varying the speed. His apparatus was a man-carrying, motorless affair; the wings, pivoted at the shoulder, being kept pointing forward at slow speeds, and sloped-back at high speeds.

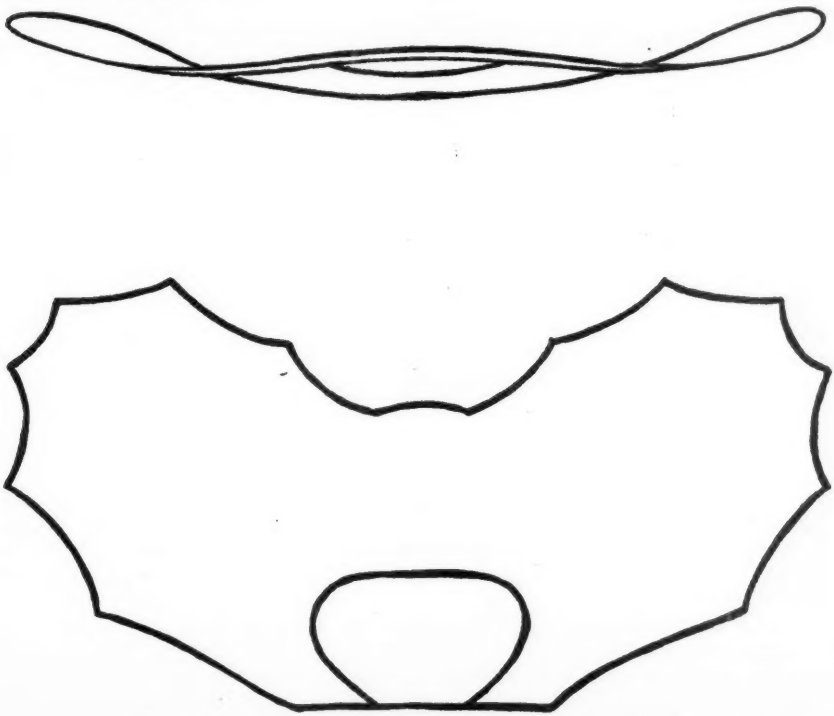


Fig. 1. Zanonia Leaf. (From Kritik der Drachenflieger)

More modern machines which combine the sloped-back wing with the negatively disposed tip differentiate themselves naturally into two distinct classes. In one of these is contained all machines of that type which in Austria and Germany is styled "Zanonia-form," the other comprises those types with which I prefer to experiment.

So far as I know, the Zanonia leaf represents Nature's solitary attempt in the Botanical Kingdom at the production of a gliding aerofoil.

Fig. 1 shows a front elevation and plan view of this extraordinary leaf. You will see that the heavy seed-pod is placed right in front of what constitutes the leading edge of this little aeroplane, so as to bring the centre of gravity into the proper position. The wings curve back on either side. As the leaf withers and dries, the tips, which are the rearmost part of the wings, curl up behind so as to present a very marked negative angle of incidence.

Ahlborn of Berlin was the first to draw attention to the gliding qualities of the Zanonia leaf. Various persons have attempted to embody its characteristics in full-size aero-surfaces, Blériot among the number. Herr Etrich has, however, given the greatest amount of time and attention to the study of this division of the retreating-wing machine.

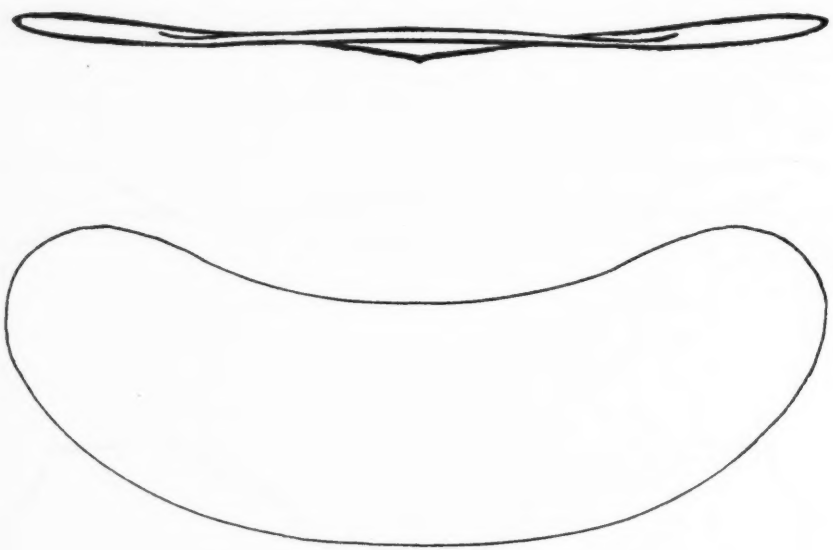


FIG. 2. ETRICH. (FROM 1905 PATENT)

Fig. 2 shows a plan and front elevation of the early Etrich glider, taken from the 1905 Patent. You will see that he has followed the leaf pretty closely. The cross-sections shown in the Patent drawing are nearly identical with those embodied in the Weiss machine; but the Weiss form was more elongated fore-and-aft, and was, I understand, evolved independently.

Later Etrich added a tail (Fig. 3), and modified his main wings considerably.

Etrich has had many followers, particularly in Germany, and doubtless the names of many machines built on these lines will occur to you, but it is with the general characteristics of sloped-back wings that we have to deal, and this division is best described, as in Germany, as the Zanonia division.

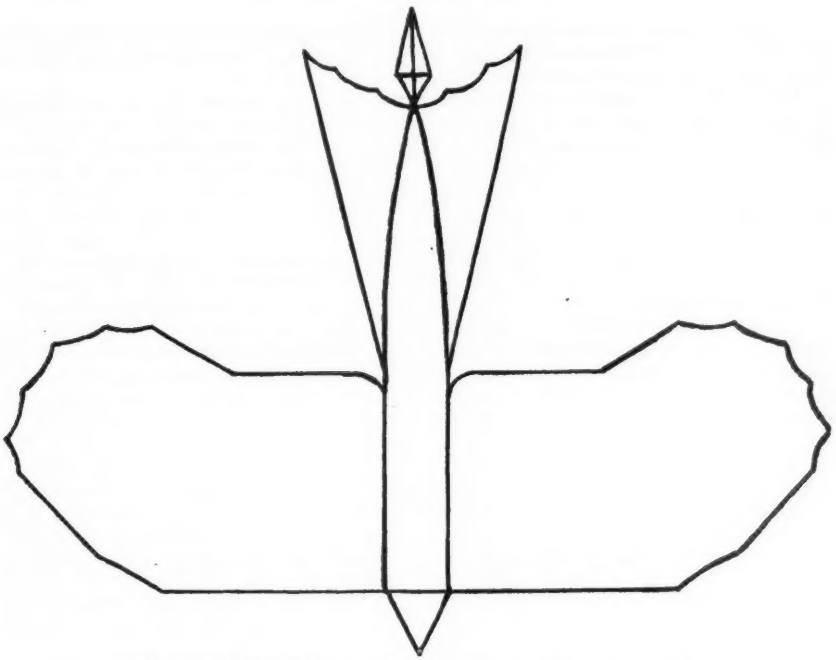


FIG. 3. MODERN ETRICH. (FROM KRITIK DER DRACHENFLIEGER)

FIG. 4A

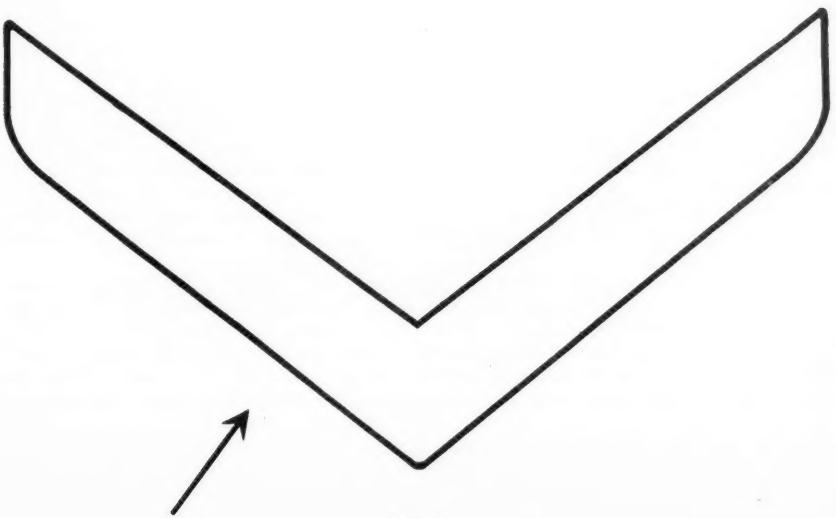


FIG. 4B

Violently opposed to the Zanonia type in most characteristics are the wing forms in the other division of the retreating-wing, negative-tip group: the division to which I have given most of my attention since 1904.*

It is, perhaps, hardly worth while devoting any of the limited time at our disposal to an elaborate description of the shape and contour of these wings. As you know, I give the wings a much more definite arrow form (see Fig. 4) than that of the Zanonia type; the tips are rolled down in front instead of rolled up behind, so that we have a concave under surface instead of a concave upper surface in this region; while the outstanding feature of the type is the fact that the whole wing forms the roof-part of a tunnel running backwards and outwards across the wing, the crown of the tunnel being sloped back at a greater angle than are the wings themselves, and the sides of the tunnel preferably converging towards the rear end. The improvement in efficiency gained by this method of construction is quite extraordinary; but as I wish to confine myself to-night to the safety devices embodied in the wings, I must for the present ask you to take my word for it that this converging tunnel tends to produce a positive pressure under the negative wing tip, so that for the same amount of negative *pressure* on the tip we are able to use a greater negative *angle* than in the Zanonia type. And it is the geometrical difference between the angle at the tip and the angle at the front of the machine which counts for most, though not for all, in natural stability.

Now the first device with which we have to deal I call the "Vanishing Wing" device. When a machine, travelling straight ahead, is struck by a side gust, the effect of compounding the air velocity relative to the machine, due to the latter's advance, with that of the side gust, is to produce as an actual resultant a single relative current which arrives from the port or the starboard bow as the case may be. Such a relative current is shown by the arrow in Fig. 4. Imagine yourself looking along that arrow. Obviously you will be looking down the tunnel under the leeward wing and across the tunnel on the windward wing. Fig. 5 is a projection showing the view of the machine you would

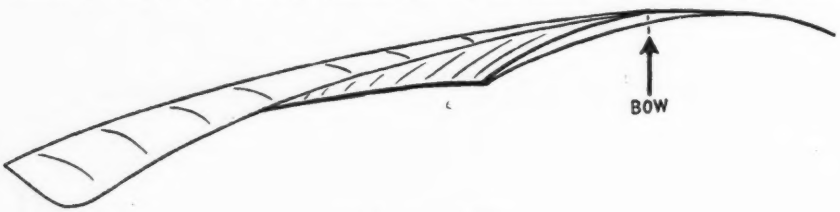


FIG. 5. DUNNE TYPE

obtain. The current is supposed to be blowing straight from your eye towards the picture. Because you are looking down the tunnel on the leeward wing, the outer part of that wing presents in this projection merely a thin line—it practically vanishes.

On the windward wing the situation is reversed. Here you are looking straight across the tunnel, and consequently not only is the amount of wing-surface that is exposed to your view considerable, but also the cambers of the sections along which you are looking are very much deeper than those along which you would look if you viewed the machine from straight ahead.

Obviously the resistance which the windward wing offers to this relative current blowing from your eye to the picture is enormously greater than that offered by the leeward wing. The machine evidently cannot for a moment maintain such an attitude. The windward wing will swing back, and the vanished leeward wing will swing forward, until the machine is facing you and pointing straight along the air-current. Thus the entire surface forms a great vane, far more powerful and far quicker-acting than anything

* My attention having been accidentally directed to fluid flow in diverging, converging, and vena-contracta pipes, it occurred to me that wings built in such forms would give pressure distributions quite different from the ordinary, and also quite different travels of the centre of pressure, and were therefore worthy of investigation. But the stability actually obtained with the first model came as an astounding surprise.

that could be obtained by the use of a fin at the back of an ordinary machine. Obviously sideways motion of more than a moment's duration is impossible; the machine will immediately nose into the new direction of motion. It would take a very violent and very sudden gust indeed to produce even a momentary condition of affairs such as we have pictured. For the instant the relative wind begins to veer so as to arrive from the port or starboard bow, the machine heads towards it and brings it back again to the normal straight-ahead condition.

FIG. 6. ZANONIA TYPE

Now turn to Fig. 6. This is a projection of the Zanoniaform showing the same condition of affairs, as regards relative wind, as does Fig. 5. The air-current is blowing straight from your eye to the picture, and striking on the starboard bow of the machine. You will notice that the condition of things in all other respects is completely reversed. Here the upturned windward tip is now in an edge-on position to your eye—that is, to the wind. The upturned leeward tip, which when viewed from the normal front is foreshortened, now presents its fullest and broadest aspect to your eye—that is, to the current. Evidently the windward wing will advance and the leeward wing will retreat. As a consequence the machine points even more away from the relative wind than before. There is nothing to stop sideways motion; on the contrary, it is encouraged. So we see that with the slightest deviation of the relative current from the exactly-straight-ahead direction, the apparatus will yaw away from it so as to turn broadside-on to it and if you care to work out the resultants of the normal flight velocity and an accelerating side-component, you will see that the yawing will persist until the apparatus has turned completely round and is heading in the opposite direction.

Now, Nature never persists in the use of a peculiar design unless it pays. Why then does she stick to this obviously erratic-flying Zanoniaform? She should just as easily construct a leaf which would curl after the manner shown in Fig. 4a. The reason is this. Nature's object is to carry the seed as far from the parent tree as possible. The withered leaves are blown off by the first wind that comes along. If they glide down nicely and steadily keeping head to wind, they will evidently land close together somewhere among the roots of the tree. Therefore Nature so designs them that, the instant they commence to glide, they swerve away from the wind, and then glide away down-wind in an erratic, rolling flight which distributes them all over the place and far away from the parent tree.

But now look at one of Nature's designs in a case where effortless balance in high, turbulent winds is her object. Fig. 7 shows the aspect presented by any one of the great

FIG. 7. SEA-BIRD

sea-birds when viewed slightly from the side as in the other two figures. You will see that the leeward tip vanishes in precisely the same manner as it does in Fig. 5. Once you have noticed this aspect of a sea-bird's wing, it continually forces itself upon your attention.

So much for the "Vanishing Wing" device. Its effect, be it remembered, is to increase the drift of the more advanced wing and reduce that of the other. Its object is purely directional.

Now let us look into the longitudinal stability. Here we have, to commence with, the ordinary longitudinal "Vee," with negative pressure on the rearmost part. Beyond that we have three other devices. The principle of the longitudinal "Vee" is well known to all of you, and it is not worth while spending much time on it. Briefly the arrangement of the centre of gravity, and centre of pressure, is as shown in Fig. 8.

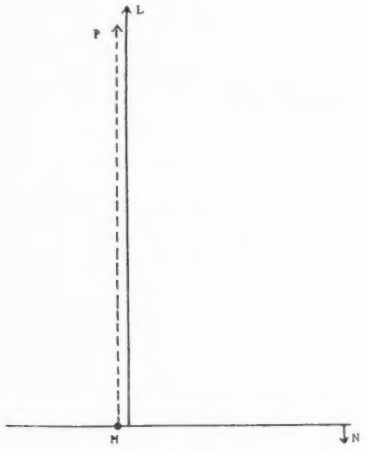


FIG. 8

M is the mass, N is the negative pressure, by which I mean down-pressure, L is the lift, and P is the resultant of L and N. Of course in normal conditions L, multiplied by its distance from M, equals N, multiplied by its distance from M. Neglecting for the moment what happens to L, it is evident that if the angle of incidence widens, the down-pressure N decreases to nothing, or even changes to an up-pressure, in either case allowing the back of the system to rise and reduce the angle of incidence to normal. While if the angle of incidence narrows, then the back of the system will get increased negative pressure, pressing it down and increasing the angle of incidence until it is again normal. With flat planes the travel of L is such as to assist this action; with curved surfaces its travel is such as to hinder it. So with curved surfaces the negative tail portion of the system has to be made more powerful in its action in order to compensate for the dangerous movements of L, and, in addition, allow a sufficient margin of righting effect.

A constant-angle-of-incidence-machine such as this is, *ipso facto*, a constant speed machine. For if the speed is accidentally reduced, the machine begins to sink: this increases the angle of incidence; P consequently goes back, which makes the machine dive slightly and thus recover its proper speed. While, if the speed is accidentally increased, the machine rises: this reduces the angle of incidence; P consequently goes forward, which makes the machine elevate and slow down to its proper speed.

Of course all this is ancient history.*

Now in the ordinary type of machine the lift pressures are distributed comparatively close to a line running transversely across the machine from tip to tip; hence in such a side-view diagram as Fig. 8 we can take them as all concentrated in the neighbourhood of L and moving as L moves.

In fact, L may be considered as their resultant.

Now I want you to notice two points.

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* My late friend, Captain Ferber, told me that Penaud was the first to explain the stabilising effect of the longitudinal "Vee." But I understand that Penaud acknowledged considerable indebtedness to Sir George Cayley.

First : That if we were to increase some and decrease others of these forces distributed along this transverse line, we might thereby make L smaller or larger, but we would not necessarily alter its position.

Second : That the stabilising back-part of the system is the comparatively very small tail plane. Being of a *fixed area*, its automatic stabilising effect for a given change of angle cannot exceed that of the change in the pressure on that small fixed area.

Now in the machine shown in Figs. 4a and 4b, the lift pressures are not distributed along any transverse line, but along lines sloping back from in front of the centre of gravity to a considerable distance behind it. So that if we draw for this machine a similar

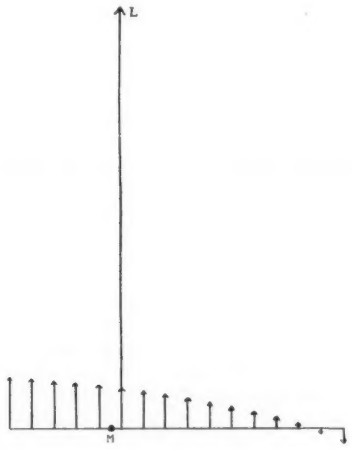

FIG. 9

diagram to Fig. 8 (see Fig. 9), L becomes the resultant of a number of little L's ranging from in front of M all the way back to N. Again the angle of incidence of the wing decreases gradually towards the negative tips, which tips actually form the negative tail, double in this case. These two points will be made clearer if you look at Fig. 4a, which shows the machine travelling straight towards you. So in Fig. 9 the distributed lifts that go to make up the resultant L must be shown smaller and smaller as they go aft, until they change their sign and become negative at N. The forward pressures are of course greater than those of an ordinary machine, the rearward pressures less, the average being the same. Now, leaving out of consideration for the moment what happens to our negative double tail, it is evident that if the angle of incidence of the whole system increases, those lift pressures which are farther from the bow will increase more rapidly than those which are more forward. This is because the farther back they are the nearer is their angle of incidence to the zero angle. Since the rear pressures grow faster than the forward pressures, the resultant of them all, L, goes back, which is the required direction for righting. If on the other hand the angle of incidence decreases, it is evident that the rear pressures die out faster than the forward pressures and the resultant goes forward. Thus, quite apart from what the negative tail-tips may be doing, *the whole of the lifting part of the surface* is utilised to assist in this manner the righting travel of L.

But besides this, look what happens to the negative tail-tips. Figs. 4a, 10, and 11 show the machine flying straight towards you. The negative part is that part where the upper surface is exposed to the flight line towards your eye. In Fig. 4a the mean angle of incidence is normal. In Fig. 10 it is greater than normal. Notice that not only is the negative part at a less negative angle, as happens with any ordinary negative

tail, but also that its area is greatly reduced. In Fig. 11 the mean angle of incidence is less than normal. Note that not only is the angle of the original part of the tail-tips more negative than before, but also that the area of the negative tail is now enormously greater.

Here for a moment we may pause and sum up the advantages we have gained over the ordinary tailed machine with its tail disposed so as to give longitudinal stability. In both cases we have the tendency of the final centre of pressure to travel wrongly owing to the centre of lift on each curved *section* travelling wrongly. Opposing this we have in both cases the changes in the amount of the pressures on the normal tail portion. But

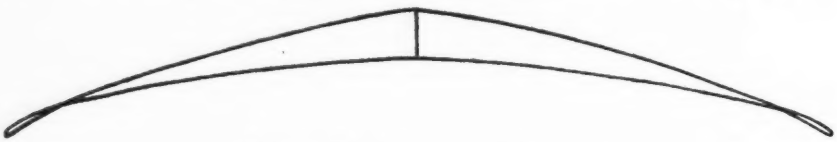

FIG. 10. FRONT VIEW WITH "NOSE UP"

FIG. 11. FRONT VIEW WITH "NOSE DOWN"

in our case we have in addition, assisting the correct travel of the centre of pressure, the change in the proportions of the entire distributed lifts on the backwardly-extending main surfaces, and also the change in the *area* of the negative tail-tips.

This latter effect may become enormous. In the case of a dive at an angle of incidence which in an ordinary machine would be less than zero, and put the whole of the main wings under top-pressure, the front part of our machine would still be lifting, while three-fourths of the entire area would have become negative-pressure tail.

A nose dive is therefore impossible. Moreover, the righting couple is so powerful, even for minute changes of the angle of incidence, that you can safely build the machine with any longitudinal moment of inertia that it is possible for you to obtain under practical conditions of construction.

All this is obtained without the necessity of introducing anything out of the way in the shape of non-lifting tail-tip surfaces in *ordinary normal* flight. For the tail-tips remain a convenient size until they are required to compete with exceptional disturbances. And, being placed at the side of the forward surfaces instead of trailing in the disturbed air behind them, they are more efficient, and so do not detract so much from the general efficiency of the whole system. Note that every single rib of the machine is in the position of a stabilising tail to those diagonally in front of it.

We have considered three separate longitudinal stability devices. These are :—

(1) Change in unit tail pressure. (The ordinary "Vee.")
(2) Change in *diagonal* distribution of Lift.
(3) Change in tail area.

There remains yet a fourth, perhaps the most important of all. This is a veritable safety device, quite supererogatory to stability, and perhaps the best name for it is the "Reserve Tangential" device.

If you look back to Fig. 9, you will notice that I have drawn all the vectors parallel to one another and normal to the supposed plane of the wings. This was for the sake of simplicity in dealing with the device we were investigating at the time. But as a matter of fact every rib of the machine has a different angle of incidence, and the vectors should properly be drawn as in Fig. 12, that is to say, as we work back from the bow, the vectors not only become smaller and smaller, but also change gradually from backwardly-inclined attitudes to upright and finally to marked forwardly-inclined attitudes. Since the more forward and more backwardly-inclined vectors are the longer, the resultant

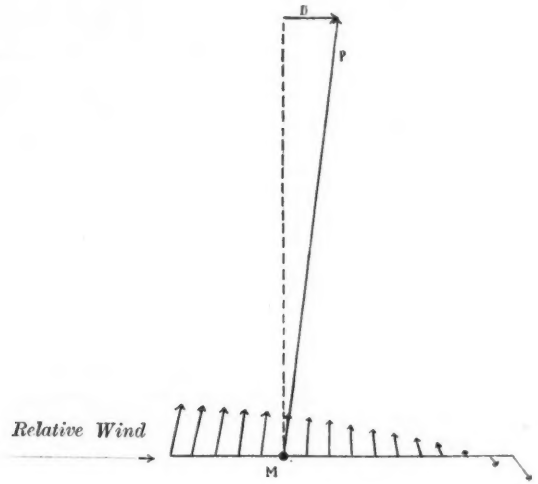

FIG. 12

FIG. 13

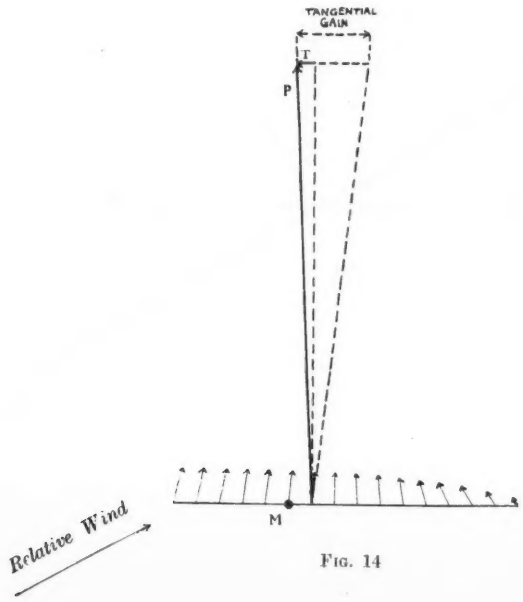

FIG. 14

of the whole lot, including those which are negative, will be also backwardly inclined. We may show it as P, and it is obvious that it has a backward component D.

Now, supposing the machine to be climbing steeply or planing at too flat an angle, so that it begins to lose speed and so lose lift. It then begins to sink and, *ipso facto*, increases the angle of incidence. This, as we have seen, is sufficient in any machine with a good longitudinal " Vee " (and especially in this machine) to cause the centre of pressure to move back, tilting the nose downwards so that the machine recovers speed. The flight path due to this action alone would be somewhat as shown by the full line in Fig. 13. The sharp descent (first pancake, and then dive) to recover lost speed might evidently have dangerous results if the ground happened to get in the way. But in our machine the increased angle of incidence produces a secondary effect. We have seen that the vectors towards the rear part of the wing increase at a greater rate than those more forward, thus moving the resultant back. But since these increasing vectors are inclined more forward than those in the more advanced portion of the wing, the resultant, besides travelling back, also takes a decidedly more forward inclination, and becomes somewhat as shown in Fig. 14. Instead of the retarding component D of Fig. 12, we now have the propelling component T, and this is just enough to carry the machine over the crest of the phugoid and save the steep plunge down the other side. As a result such descent to recover speed as may be necessary is done at a decent easy angle, somewhat as shown by the dotted line in Fig. 13, instead of in a highly dangerous combined pancake and plunge. In brief, this reserve tangential affords an ever-available and entirely automatic means of temporarily increasing the speed in emergencies without the immediate necessity of diving. The effect this has on the smoothness of the flight-path in high winds is quite amazing when first experienced.

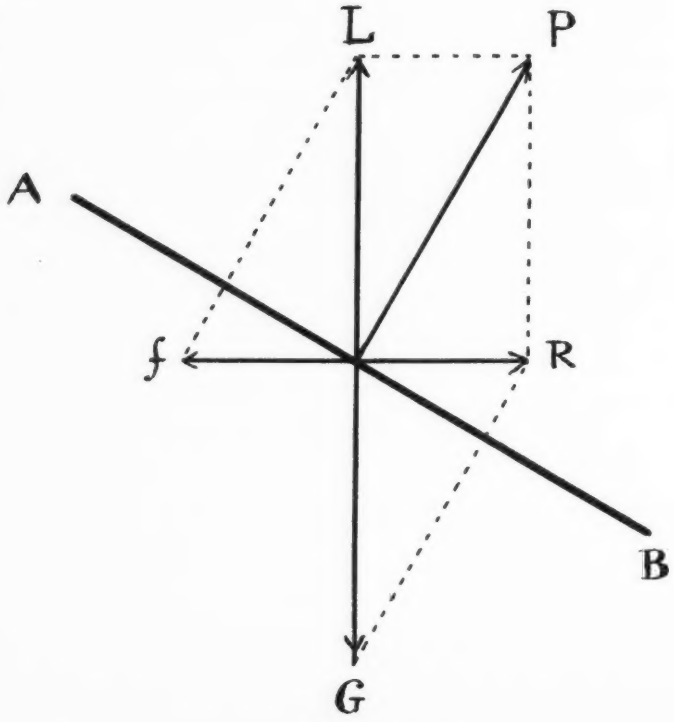

FIG. 15

One curious result of this reserve tangential—curious, that is, to the spectator—is the ability of the machine to maintain itself under full control at apparently impossibly large angles of incidence.

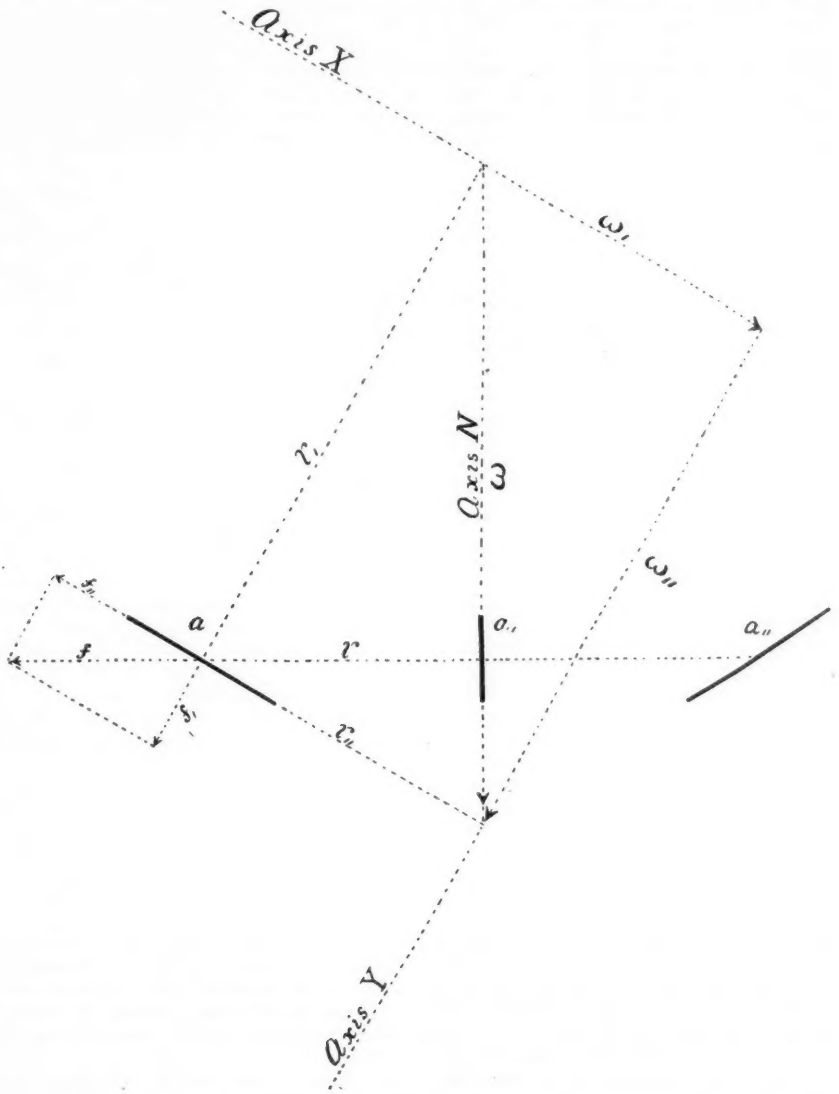

FIG. 16

These four longitudinal devices, utilising as they do the entire aeroplane surface probably confer the maximum longitudinal stability obtainable, and *prima facie* considerably greater than that which can be obtained by the manipulation of small subsidiary surfaces attached to a main unstable surface. The directional stability also

we have seen to be very considerable. Let us now examine the effect of these two properties in a state of affairs where the machine is tilted sideways.*

Since the days when Wilbur Wright first showed us what banking really meant, every student of aeronautics knows the old diagram shown in Fig. 15. Here AB is a front or back view of the tilted plane, P is the air-pressure, G is gravity, and R the resultant of P and G. The force f is the centrifugal force necessary to balance R; or, looking at it another way, f and P together have the resultant L which balances gravity. If that force f can be obtained, the system is in equilibrium, and the necessary support against gravity is maintained. Lacking that force, there is neither equilibrium nor a continuity of support, and the machine must fall, *no matter what the reserve of power.*

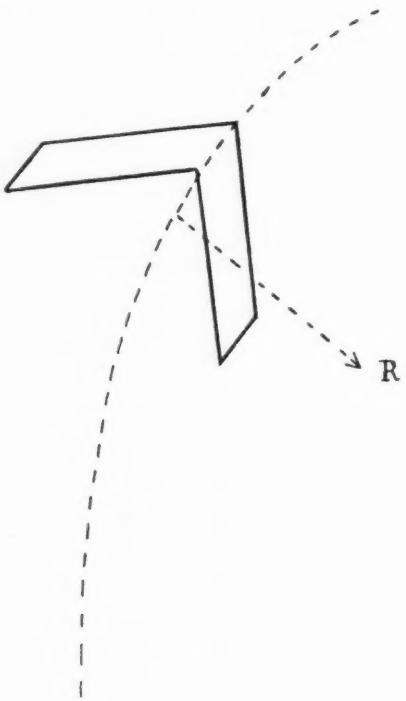

FIG. 17

Recovery there may be, due to a magnificent sideslip bringing some fin- or dihedral-angle effect into operation, but our object is to maintain steady equilibrium throughout the flight and adequate support at all times, and we particularly want to avoid these falling, slipping, rolling evolutions. Therefore, the equilibrating centrifugal force f must be obtained at all costs, which is equivalent to saying that the machine must be made to revolve about some such axis as N. (See Fig. 16.)

Now the revolution about the axis N, with radius r, and angular velocity ω, and centrifugal force f, can be resolved into two simultaneous revolutions, one about the axis X with radius r_1, and angular velocity ω_1, and the other about the axis Y, with radius r_{11}, and angular velocity ω_{11}. The centrifugal forces due to these simultaneous revolutions are respectively f_1 and f_{11}, which combined have the resultant f. The revolution about the

* As if, for example, it were deliberately banked over by the use of the ailerons, which were immediately afterwards returned to their normal position.

axis Y is in this case evidently a purely directional manœuvre, due to tail or fin or some equivalent. The revolution about the axis X is a movement of elevation involving a longitudinal manœuvre.

In order, therefore, that the aeroplane shall revolve round N following the path a, a_1, a_{11}, and so produce the requisite force f, it is necessary that it shall have sufficient directional stability to follow with its bow the lateral deviation in the trajectory of its mass induced by the lateral component of R (Fig. 15), and sufficient longitudinal stability to follow with its bow the upward deviation in the trajectory of its mass induced by the upward component of R.* The machine under discussion fulfils, as we have seen, both these requirements.

This resolution of the turn into two components is not necessary unless we want to understand in detail exactly what is happening. For a general comprehension of the idea, Mr. Berriman's lucid statement that, granted " weathercock " stability, a machine will follow with its nose any deviation in its trajectory induced by R, is less complicated. But I have shown the full analysis, in order to introduce to aeronautical students this method of resolving banked turns into components in the planes controlled respectively by rudder and elevator. It enables you to see what is actually happening, without the usual necessity of assuming some complicated interchange of the relative functions of these organs.

We have it then established that if the machine be in a tilted position with one wing lower than the other and all controls normal, it will commence to circle towards the depressed side. Fig. 17 shows the aeroplane circling thus, seen from above. I have shown the machine as heading straight into its curved path, and it will presently be obvious that such a position cannot be maintained.

In the first place the outer wing in order to keep up would have to travel through a greater arc than the inner wing in the same time, and so overcome greater resistance. Obviously this outer wing will tend to lag behind.

In the second place the outer wing would tend to be depressed, and this for two reasons. First, the pressure increases gradually towards the outer tip, because the arc described by each portion of the wing increases in length as you travel out towards that tip. And, as the pressures increase, so are they applied to less and less positively inclined portions of the wing, till at the outer part, where the pressures are greatest, the tip is actually negatively inclined.

Now, in the early days of my experiments, I used to think that this negative inclination of the outer and faster-moving tip was sufficient to account for the fact that the machine—if turned by an ordinary rudder—depressed the outer wing. In this I was wrong. Later quantitative analysis of the positive and negative couples showed at once that, with the small amount of negative surface we use, the counterbanking couples were utterly insufficient to balance the banking couples due to the increased pressures on the lifting parts of the outer wing and the shortage of pressure on the inner negative tip. In this I believe I have the support of Mr. Hume Rothery, who calculates that in order to obtain a counterbanking result one would require to have a quarter of the negative surface inclined so as to come under negative pressure. I think it would be impracticable to do this with the class of machine and motor we have at our disposal at present.

But if a practicable negative tip does not produce sufficient counterbanking, we must look for something else in the construction which supplies the deficiency.

Now from long experience with earlier arrangements of surface—as far back as 1904—I had managed to acquire a fairly complete empirical knowledge of the constructional device necessary to complete the turning stability. But this knowledge remained empirical until Professor Bryan supplied me with the proper explanation. He pointed out that an aeroplane travelling round a circle is not only describing a circular path, but is at the same time spinning round its own vertical axis.

The idea is a little complex at first, and one is apt to confuse, as I did, the resultant motion of the tips with the conception we have already taken into account, viz., that the outer tip is merely describing a bigger arc than the inner. But the two phenomena are really totally distinct. This will be evident if we look at Fig. 18. Here the aeroplane

* *i.e.*, it must elevate as the angle of incidence is reduced by this upward deviation.

is travelling round the centre of the several concentric circles. These concentric circles show, where they meet the leading edges of the wings, the actual relative paths of the air-currents at those places. Because these wing edges slope back across the line joining the centre of gravity to the centre of the circles, and for no other reason, the air-currents impinge on the inner tip from a direction which runs more from inside to outside than does the direction of the air-current in normal straight-ahead flight. That is to say, they are able to strike on the underside of the inclined tip by getting at it from the inside—down the tunnel—and so lift this tip although it is geometrically negatively inclined to the

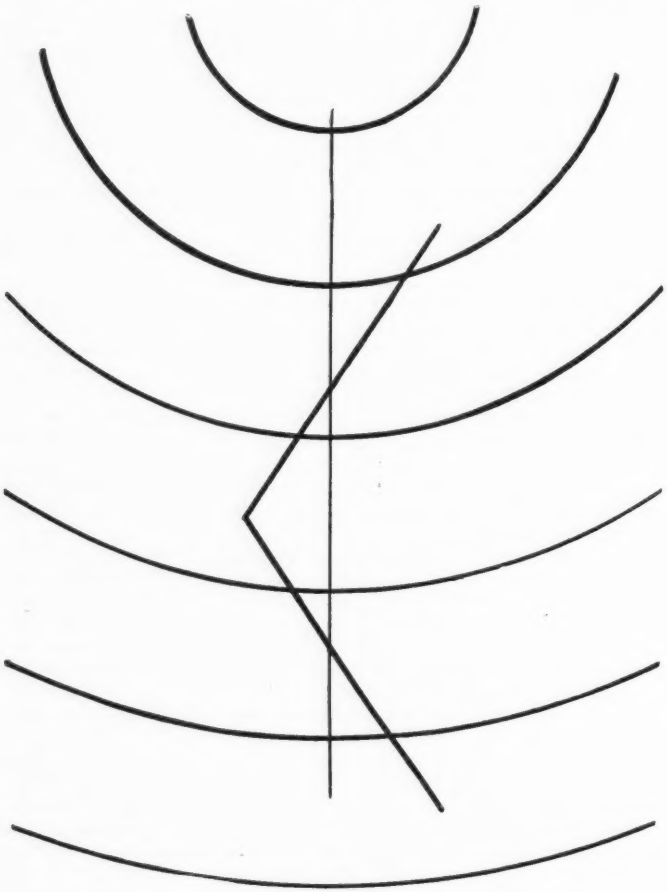

FIG. 18

straight-ahead direction. While on the outer tip the currents impinge from a direction which runs more from outside to inside than does the direction of the air-current in straight-ahead flight, and if you will look again at Fig. 5 you will see that this means that the surface is more negatively disposed to these currents than it is to those coming from straight-ahead in normal flight, and so is more pressed down than in normal flight. While, with regard to the surfaces ahead of the line joining the centre of gravity to the centre of the circles, the currents on the inner wing impinge in a direction which runs more from

outside to inside than the normal, and another glance at Fig. 5 shows us that the positive surface we find here opposes to them a deeper camber than it does to normal straight-ahead currents. The reverse obtains where the outer forward surfaces are concerned. Thus, again, the inner wing gets more lift and the outer wing less than in normal flight.

With a wing edge set parallel to the line joining the centre of gravity to the centre of the circles, this phenomenon would obviously not occur. With a " Zanonia " leaf form the lifting and depressing effects would be reversed, tending to increase banking instead of checking it, which, I imagine, is why the " Zanonia " form seems to do better in practice when the slope back of the wings is comparatively slight.

Now add to the effect we have just examined the fact that the outer tip is travelling faster than any other part of the machine, and we have ample explanation of the fact that this machine counterbanks when turned by an ordinary rudder.

Now we can get back to Fig. 17. We have ascertained that the tilted aeroplane cannot maintain the position shown, but that, if left to itself, the outer wing will sink towards its normal level, the centripetal force R diminishing towards zero as this occurs. Meanwhile, as we saw before, this wing also tends to hang back, and the inner wing to set itself forward. The machine is striving towards a position of equilibrium for that particular radius of turn, but never reaches it, because as it swings outward and levels up so does the turning radius increase and the centripetal force diminish. Equilibrium is only attained when the radius is once more infinity and the machine is travelling straight ahead on a level keel.

It follows that no matter how narrow or steeply banked the turn, the aeroplane is always striving to reduce the bank and at the same time widen the turn. As a matter of fact, I find in practice that if, as we are supposing, the original tilt had been given by the action of the ailerons, the machine levels up just about as fast as you can return those ailerons to their normal position.

It is, therefore, impossible for the turn to develop into a spiral dive. Again, no matter how steep the bank, the machine will always turn so as to produce sufficient centrifugal force to give support against gravity. A side-slip is, therefore, impossible, even without calling to our aid the various devices I shall explain later when we come to deal with the purely lateral stability.

Now instead of allowing the tilted machine to spring back level, we can, by means of ailerons, ease the lifting and forward-thrusting pressure on the inner extremity by letting the back edge of that part fly up, and reduce the downward and backward thrusting pressure on the outer extremity by letting the back edge of that extremity drop. In this position we have turning equilibrium. An examination of Fig. 18 will render it evident that if a gust turns the nose of the machine inward, so as to narrow the circle, we shall immediately get an increased counterbanking effect and increased resistance on the outer wing ; while, if the nose be turned outward, we shall get the reverse effect. By modifying the geometrical angle of the tips, we have made the radius of turn where the machine can attain equilibrium less than infinity. If we continue to raise the inner back edge and lower the outer back edge, so as to get a definite banking and inward-turning couple, the machine will bank and turn in response until the narrowed circle again brings sufficient counterbanking effect into action to neutralise the new setting of the ailerons.

You will perceive from this that, in order to commence a turn, we have to put definite negative pressure on the inner aileron and positive pressure on the outer, but that the machine then sets itself to such a position, and turns at such a radius, that the pressure on the ailerons is practically nothing, as in normal flight. Throughout the steepest banks and turns, and indeed throughout every manœuvre with this machine, the ailerons remain almost exactly balanced ; and it is only when one wants to change position *suddenly* that one has to put any realisable pressure on the levers. As a result the machine is probably the most sensitive to control in existence.

Now for the LATERAL STABILITY.

It will be obvious from what has gone before, that we start out to tackle this problem under unusually pleasant conditions, for we have to begin with the comfortable assurance that it does not really matter to what angle the machine gets blown over—it cannot lose equilibrium, and side-slips and spiral dives are impossible. So far, therefore, as *safety* is

concerned, the lateral problem has been adequately dealt with. All that we have to do is to devise some means of ensuring lateral *steadiness*.

Lateral stability devices as a rule consist of combinations of dihedral or kathedral angles or their equivalent fins. A dihedral angle exists where the wings are flexed so as to slope away from the air current ; a kathedral where they slope towards that current.

A kathedral angle is dangerous because its action becomes more powerful as it yields to the gust, and so, if it is strong enough to rotate the machine at all, it may roll it clean over. This will be apparent if you look at Fig. 19 which shows a front or back view of a kathedral wing. Obviously the wing will not arrive at a position of equilibrium to the

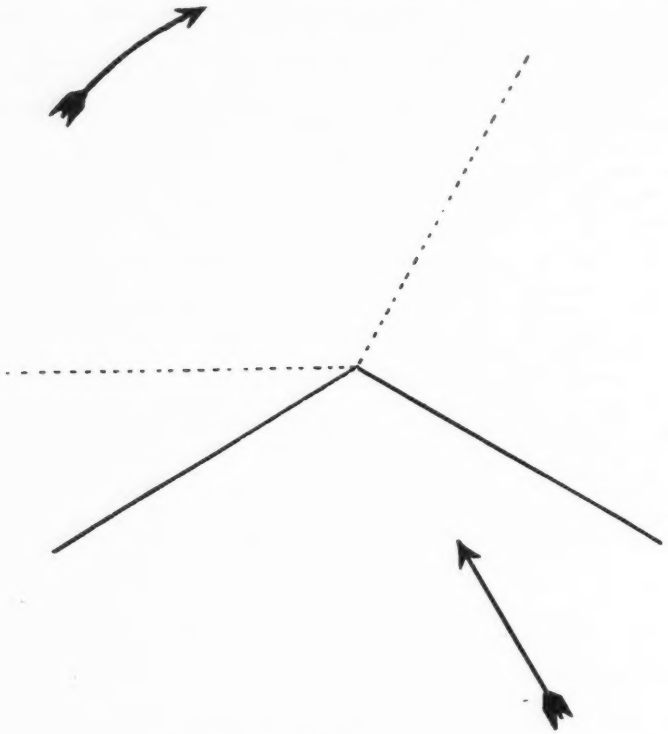

FIG. 19

wind represented by the arrow until it has rolled completely over to the position indicated by the dotted lines, the direction of rotation being shown by the curved arrow. A dihedral angle on the other hand begins to lose its power the moment it yields, and reaches a position of equilibrium with a comparatively small rotation. Fig. 20 shows such a wing, and it can be seen that a rotation of a few degrees in the direction of the curved arrow will bring it to a position of equilibrium.

Now we use to commence with a dihedral angle which tends to roll the machine towards the windward side. This statement sounds absurd, so we must explain that it is a *negative* dihedral angle. To understand what I mean by this, turn to Fig. 21. It shows a front or back view of a surface which is under negative pressure, that is to say the wind strikes it from above. If then this wind has a lateral component, as has the arrow representing the wind in the diagram, the surface will roll a few degrees in the direction of the curved arrow and attain the position of equilibrium shown by the dotted lines.

Comparing Fig. 21 with Fig. 19, we see that there is a very considerable difference between a positive kathedral and a negative dihedral, even though both cause rotation in the same direction.

This negative dihedral has all the stabilising properties of the positive dihedral, but operates in the opposite direction. If you will look back to Fig. 4a you will see the angle in question is formed by the negative tips of the machine.*

Now opposed to this we have at the front of the machine a very slight positive dihedral effect, due to the coning of the wings making it easier for the air to get away outwards than inwards, and also to the fact that the windward wing opposes a deeper camber to the current than does the leeward wing.

Each of these opposing devices being dihedral, and so—even if unopposed by the other—tending to take up a position of equilibrium, it is not of very great import whether they exactly balance each other or only nearly so. But what is of importance is that since each is strongly resisting the action of the other it effectually damps out any oscillations that other might tend to produce.

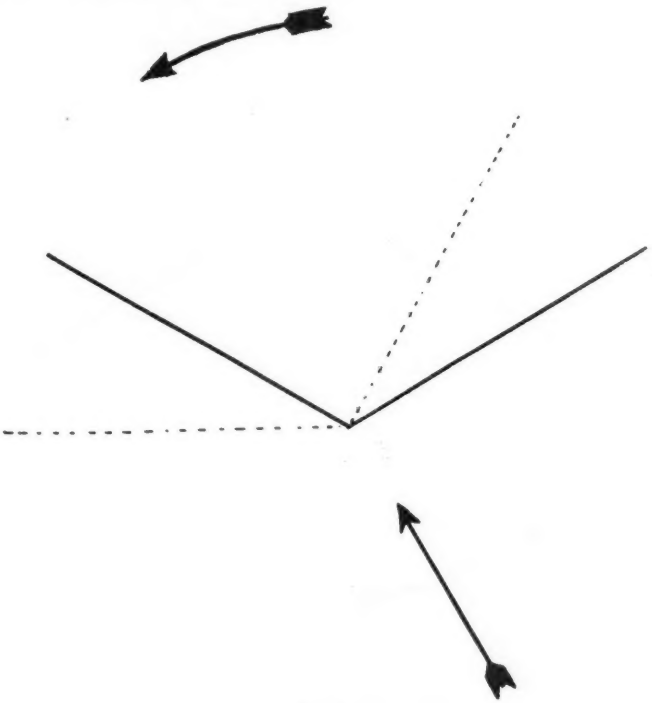

FIG. 20

We have, however, found no difficulty in so balancing the opposing couples that ordinary side gusts, such as one encounters when flying in moderate winds, produce absolutely no perceptible lateral disturbance.

But side gusts unfortunately are not always steady. We have to deal with fierce gusts, irregular gusts, gusts with an upward trend or a downward trend, local side-puffs striking one portion of the wing and not the other, and narrow-diametered "remous."

* The tips of the "Zanonia" leaf form a negative kathedral, which rolls the leaf the same way as does a positive dihedral, but lacks the stability of the latter.

Now we noticed while dealing with the longitudinal stability, that the amount of negative surface exposed depends upon the angle of incidence. If you look again at Figs. 4a, 10 and 11, you will note that there are two points in the span where the leading edges cross the back edges. Inside these points the wings are positive, and would lift the windward side. Outside these points they are negative and would depress the windward side on account of their negative dihedral effect. You will see that as the mean angle of incidence of the machine grows smaller, these points, where the edges cross, move inwards, increasing the negative dihedral surface and decreasing the positive surface.

You will also note that at normal flight angles the negative dihedral surface is very small. To carry a lot of unnecessary negative surface until you actually needed it would be a source of inefficiency. Our negative dihedral surface develops as it is required.

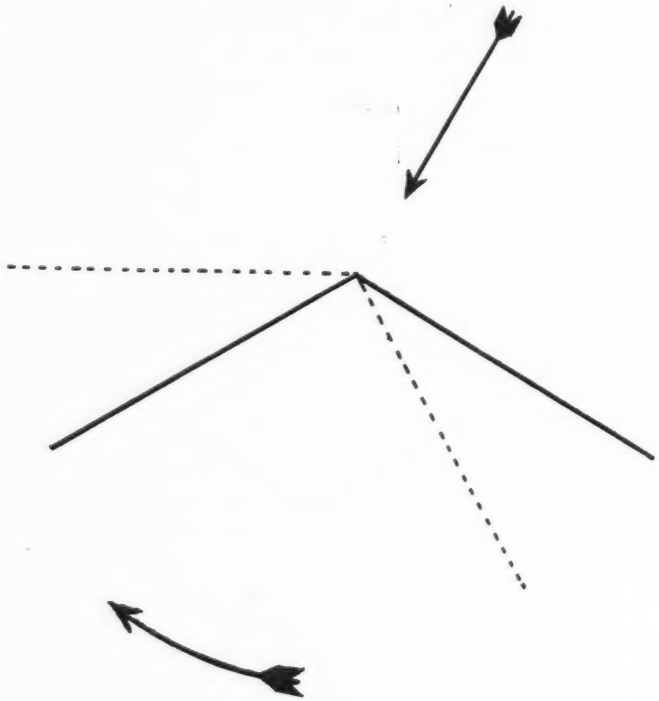

FIG. 21

Thus, if, after viewing the machine from in front, you were to step to the right or left, you would notice that as you move round, so does the point on the wing nearest you, where the leading and trailing edges appear to cross, travel more forward towards the bow. For example see Fig. 5, which shows the aspect presented to an unusually strong and sudden side gust, and note that a very large portion of the near wing has become negative, the far wing having practically "vanished."

Now look again at Fig. 4a. If the side gust affects the distribution of pressure on the wings in such a way as to render the negative dihedral couple (*i.e.*, the windward-rocking couple) too powerful; which is equivalent to saying that the negative pressures in the region of the negative tail-tips are augmented more than those on the positive surfaces: the effect will obviously be not only to roll the machine to windward, but also to *elevate* it.

But elevating the front has, as we have seen, the effect of reducing the amount of the negative (windward-rolling) surface and increasing the amount of the positive (leeward-rolling) surface. Thus the windward roll started by the unevenly distributed gust is almost instantly checked.

Conversely, if the gust accentuates the effect of the leeward-rolling couple, which is equivalent to saying that the positive pressures are augmented, the effect will be not only to roll the machine to leeward, but also to depress the bow—for the centre of positive pressure is behind the centre of gravity. Depressing the bow, as we have seen, increases the amount of the windward-rolling negative surface, and decreases the amount of the leeward-rolling positive surface.

Flying this machine in very " bumpy " air, or side-on to a thoroughly bad wind, one notices little sudden movements, gently checking themselves, about axes which run, roughly speaking, parallel to the backward-sloping wings.

And so we come to our final device. Part of this I have explained so often that I think everyone here must understand it pretty thoroughly ; so I will merely point out once more, as briefly as possible, that when the wind strikes this machine somewhat on the side as shown by the arrow in Fig. 4b, the windward wing meets that wind with its broadest side towards it, and the leeward wing meets it in the end-on position.

Now everyone knows that Langley proved experimentally that if you expose two long narrow planes at a small angle of incidence to the wind, the one broadside-on with its longer edge forward and the other end-on with its shorter side forward, the former will experience the greater pressure. Let us refer to this superiority of the broadside-on plane as " Aspect-Ratio Effect."

Now, curiously enough, hardly anyone seems to have noticed as anything worth remarking, that the experiments showed further that as the angles of incidence are gradually increased, this disproportion in pressure rapidly diminishes, till, when the angles are thirty degrees, the pressures are equal, while beyond that angle the conditions are actually reversed and the pressure on the end-on surface becomes the greater.

So in such a condition of affairs as is depicted in Fig. 4b, the pressures, negative as well as positive, all over the right wing are greater than those on the left wing. Now, if the machine rotates to leeward, the angle of incidence of the positive (leeward-rolling) portion is increased, and so the aspect-ratio effect of that part is diminished. But the negative angle of incidence of the negative (windward-rolling) portion is *decreased*, and so the aspect-ratio effect on that portion is augmented. Exactly the converse occurs if the machine is rotated to windward by an over-powerful negative dihedral couple.

This damping and stabilising action has to be regarded as superposed upon the various lateral stabilising effects we have already considered, which is, perhaps, a rather complicated idea to absorb.

Under ordinary conditions of flight its action is but slight, and is in general a damping one. It renders the effect of the alteration in the relative proportions of positive and negative surface due to change of mean angle of incidence less sudden in its action, while it adds to the damping effect the opposing dihedrals have on one another.

But its great value lies in this : that apparently no matter how sudden, violent, and unevenly applied be the gust, you cannot possibly be blown over either way to much beyond 30 degrees. I say " apparently," because I have not yet flown the machine in the hurricane which would be necessary to put this quality to actual test, and indeed I find that in this case I have quite a strong conviction that theory is preferable to practice.

To sum up. We have :—

For Lateral Safety.

(*a*) The fact that no matter how the machine be banked, it will automatically supply sufficient centrifugal force to keep up the support against side-slip.

(*b*) The fact that, owing to its tendency to level up from any bank and widen out any turn, it cannot spiral dive.

(*c*) The presumed fact that it cannot be blown over to anything much beyond 30 degrees, owing to change in aspect-ratio effect.

(*d*) The extreme sensitiveness to control.

For Lateral Steadiness.

(*a*) The negative dihedral behind the centre of gravity.
(*b*) The opposition of this by a positive dihedral in front of the centre of gravity.
(*c*) The alteration of the relative surface-proportion of these, whenever one gets excess pressure.
(*d*) Superposed on these :—The variable aspect-ratio effect.
(*e*) Superposed again on these :—The tendency of the machine to turn towards any bad side-gust, thereby making it less of a side gust.

Contrary to the general idea, and certainly contrary to what I myself expected when I began work on this type, the lift per horse power is quite good, while the speed is, I think, somewhat superior to that of the ordinary wing. The gliding angle of the aerofoil is, I believe, much better than that of an ordinary aerofoil *with its tail*.

The following certificate supplements the report in the Journal for January, 1911, in that this second trial was undertaken with an official observer on board.

ROYAL AERO CLUB OF THE UNITED KINGDOM

Certificate of Performance No. 1. Flight of Aircraft uncontrolled by pilot. (Under the Competition Rules of the Royal Aero Club.)

This is to Certify that on the 11th December, 1912, a Dunne Biplane was entered for trial by the Blair Atholl Aeroplane Syndicate, Limited, the object of the trial being to show the behaviour of this Biplane when flying without being controlled in any way by the pilot.

Particulars of Aircraft

Type. Dunne Biplane, two-seater. Overall span 46 feet. Total lifting surface, 552 square feet. Motor, 50—60 h.p. 4 cylinder Green.

Controls : Hand levers only, no automatic controlling mechanism, gyroscopic or otherwise, fitted.

Description of the Trial

The trial took place on Salisbury Plain on the 16th and 17th December, 1912. On the first flight on the 16th the wind was blowing in gusts up to twenty miles per hour, and the pilot ceased to manipulate all controls for a period of one minute five seconds, whilst flying over a spot where irregular disturbances of the air were, from the actual experiences of the official observer, known to prevail. During this period the aircraft was quite stable laterally, there being an absence of both quick jerky movements and periodical rolling. The apparent effect of a gust was to cause the aircraft to turn steadily to the right or left.

The second flight on the 17th was made under slightly better weather conditions, and the pilot ceased to manipulate all controls for two periods of one minute each. During one of these periods the controls were locked, and the aircraft described a complete circle of 360 degrees, banking of its own accord at the correct angle. There was no feeling of side wind on the face of the Official Observer, thus showing absence of sideslip either inwards or outwards.

[To the above report may be added the additional information (i) that, at the time of the first flight, pilots flying 80 h.p. monoplanes reported using their controls continuously. (ii) That the engine of the Dunne machine was " missing " the whole time.—Ed.]

ANNUAL GENERAL MEETING

THE ANNUAL GENERAL MEETING of the Aeronautical Society of Great Britain was held on Wednesday, March 26th, at 8.0 p.m., at the Royal United Service Institution, Whitehall, S.W.

The Chairman of Council, Major-General R. M. Ruck, C.B., R.E., presided.

The CHAIRMAN : The business of this meeting is set forth in Rule 37. It is to receive and approve the report of the Council on the state of the Society, and the Balance Sheet of Aerial Science, Ltd. To discuss and determine such questions as may be proposed by council or voters (in this case none) and to fill the vacancies on the Council for the ensuing year.

The Chairman then read the Council's Report for 1912–13.

COUNCIL'S REPORT, 1912-13

THE present Council, on assuming office in March, 1912, accepted the policy of the preceding Council, as enunciated in their Report for 1911-1912, as that best calculated at the present time to advance the objects of the Society.

The main feature of this policy is the development of the technical side of the Society, which came into being in accordance with the scheme adopted at the General Meeting of September 25, 1911.

The results of the year's work, the Council consider, have been satisfactory.

Meetings.—The programme of fortnightly meetings for the reading and discussion of technical papers, which commenced on November 13, 1912, and will extend until May 21, 1913, is believed to be the most comprehensive yet organised by the Society. Excellent discussions have taken place, and the verbatim reports of these Meetings (published in the quarterly Journal of the Society) form a collection of the leading technical opinion of the day.

That it should have been possible to embark on so extended a programme is due in large measure to the help given by Mr. Mervyn O'Gorman, to whom the thanks of the Society are due for his valuable assistance in connection with the Meetings.

Once again has the Society been fortunate in those who have presided at its Meetings. The presence in the Chair of Sir John French, Chief of the Imperial General Staff, on the occasion of Major Sykes's lecture on Military Aviation, was a specially noteworthy compliment to the Society's work for military aeronautics which the Council desire gratefully to acknowledge. General Sir Horace Smith-Dorrien, K.C.B., D.S.O., *p.s.c.*, General Sir James Grierson, K.C.B., C.V.O., Brigadier-General D. Henderson, D.S.O., C.B., Dr. R. T. Glazebrook, F.R.S., Professor W. C. Unwin, F.R.S., have also given their valuable support to the Society's work.

The Royal United Service Institution have continued to extend to the Society the same consideration as formerly in connection with the use of their admirable theatre.

Public Safety and Accidents Investigation Committee.—At a Meeting of the Society on December 18, 1911, the Chairman very earnestly voiced a desire, which had already found expression in France, that some accredited body should investigate accidents to aircraft and make recommendations with a view to their prevention. The Council therefore welcomed the opportunity, which occurred shortly after the Meeting referred to, of co-operating in the work of the Committee constituted by the Royal Aero Club, as affiliated to the F.A.I., with the above objects in view.

Wilbur Wright Memorial Fund.—The inception of this Fund, the interest on which constitutes an annual premium for the delivery of a Wilbur Wright Memorial Lecture, arose from a proposal by Mr. T. W. K. Clarke at a Meeting of the Council on June 12, 1912, which was enthusiastically taken up and the Fund inaugurated by those present.

The Council are much indebted to Mr. Griffith Brewer for the very great assistance he has rendered on behalf of the Fund. By enlisting the valued support of Lord Northcliffe and others he has assured its success and given it a representative character which it would not otherwise have had.

It was decided that the Fund should be administered by Trustees, and the following gentlemen have accepted the Council's invitation to serve in that capacity :—

> Lord Northcliffe, Mr. Griffith Brewer, Professor T. A. Hearson, Mr. F. K. McClean, Mr. Alec Ogilvie, Colonel H. E. Rawson, C.B., Mr. B. Woodward, Major-General R. M. Ruck, C.B. (Chairman of Council).

Mr. Horace Darwin, F.R.S., has accepted the invitation of the Council to read the first Wilbur Wright Lecture at the Royal United Service Institution on May 21, 1913, at 8.30 p.m.

Fellows Election.—The Election of the first Fellows of the Society, which was postponed for a time at the wish of the first Associate Fellows, is now being proceeded with, and the result will be announced at a later date. It is intended to proceed as soon as possible with the election of additional Fellows.

Associate Fellows Election.—The second Election of Associate Fellows took place in June, 1912, and resulted in the addition of twenty-three names to the Roll.

The third Election is now under way, and the result will be announced later.

The Council having felt the need for some test to render the task of selection and recommendation of candidates for Associate Fellowship less difficult, the existing Associate Fellows were asked to give their views as to the desirability of instituting an entrance examination for the grade. At a Meeting held on September 4, 1912, they decided that for the present the test for Associate Fellowship should be a thesis, to be written by the candidate on a subject selected from a list compiled by the Council. The judging of the theses to be undertaken by two or more persons specially selected by the Council for the purpose.

They further recommended to the Council the desirability of instituting an elementary examination in aeronautics and of appointing a lecturer in elementary aeronautics as soon as possible. Although the Council have felt unable at the present time to incur the expense of giving effect to these latter proposals, they are hopeful that at no distant date it may be possible to carry them out.

Change of Secretaryship.—On August 14, 1912, Mr. T. O'B. Hubbard relinquished the Secretarial duties, which he had so ably performed for three years, in order to devote himself to an active flying career in the Royal Flying Corps. In recognition of his services to the Society he was created a Life Member and presented with a sword and cheque, subscribed for amongst the Members.

His place was taken by Mr. Bertram G. Cooper (a Member of Council until the above date), who, however, for the present is unable to relinquish his other work in order to devote his whole time to the post.

Educational Lectures.—The Working Men's Club and Institute Union having approached the Society with a view to obtaining Educational Lectures on Aeronautics for their affiliated clubs, the Secretary has prepared and delivered such Lectures to several clubs in the London district, and has had large and attentive audiences. The extension of these Lectures to the provinces is in contemplation.

Library.—The maintenance of a complete and up-to-date technical Library is an important function of the Society, which has not been lost sight of. The Society is much indebted to Mr. T. O'B. Hubbard for the gift of about 120 books and pamphlets, many of which are very rare, and lately had the good fortune to be able to acquire a unique press-cutting album formerly belonging to the late original Secretary of the Society (Mr. Fredk. Brearey), showing the history of the Society from its commencement until about 1894.

The collection of lantern slides has been of great use to Members giving lectures during the year.

Loan Exhibition, Science Museum.—The Chairman and Secretary of the Society, by invitation of the Director, were members of the Advisory Committee which assisted in

the compilation of the temporary collection illustrating the development of aeronautics recently on exhibition at the Science Museum, South Kensington, which included the relics belonging to the Society, comprising the Pilcher and Lilienthal gliders, parts of Stringfellow's models, rare prints, posters, books, &c.

Aero Show, Olympia.—The Society's exhibit at Olympia formed an historical collection of great interest and was a great attraction to visitors, who appreciated its personal appeal amongst what were to many of them technical exhibits difficult of comprehension.

It is hoped at the next Show to contribute a collection of scientific apparatus used in the design, construction and navigation of aircraft, so arranged as to exhibit to the public the scientific side of aeronautics in a manner capable of being understood by non-technical persons.

Alteration of Associate Members' Subscription.—The subscription of Associate Members was altered, at the instance of the Council, by General Meeting on May 16, 1912, from 10s. to £1 1s., and the entrance fee to that grade abolished.

Finance.—It will be within the recollection of Members that the finances of the Society have not been in a satisfactory position for many years. The yearly expenditure has considerably exceeded the income from Members' subscriptions, and the generosity of one Member, Mr. Patrick Alexander, has alone kept the Society from bankruptcy. His donations, which have amounted in all to over £1,200, ceased in 1910, since when the yearly excess of expenditure has been met from the accumulated balances of past donations, which are now exhausted.

Taking the eleven years ending December 31, 1911, the average excess of expenditure over subscription income has been about £140 per annum and for the last three years of that period over £200 per annum.

Realising the above unsatisfactory financial position, the Council made an exhaustive inquiry last summer into the possibilities of reducing expenditure, with the result that considerable savings have been effected. On the other side of the Account the subscription income has been increased owing to the creation of the technical side, and to a large increase of Members in the autumn of 1911, whose subscriptions and entrance fees appear in the statement of accounts for 1912. In the past year, therefore, the subscription income exceeded the expenditure by about £100. Although it may be said that this satisfactory result is due to abnormal causes, the improved financial state of the Society will be evident from the fact that without counting on any increase of Membership the expenditure for the present year will not, the Council consider, exceed the income exclusive of any donations.

Only by the most rigid economy, however, can this result be attained, and as yet no adequate salary can be given to a Secretary, nor can funds be allocated to Scientific Research, which it is so desirable to encourage.

The Council again urge the absolute necessity for increasing the membership, and appeal to each member personally to obtain at least one new member during this year.

The CHAIRMAN: I have to explain that owing to the unfortunate intervention of the Easter holidays it has not been possible for the auditor to get out the account and balance sheet in time for it to be circulated before the meeting. These accounts will, however, be sent to the members very shortly.* The report is now open for discussion should anyone desire to comment on it.

As there are no remarks, I shall be glad if some member will propose and second the adoption of the report.

[This was done and the report passed *nem. con.*]

I have now to explain the position with regard to the Council.

After the election in March, 1912, the Council consisted of:—

TECHNICAL		NON-TECHNICAL	
Elected Mar., 1912.	Remaining from previous Council.	Elected Mar., 1912.	Remaining from previous Council.
1. T. W. K. Clarke.	5. Griffith Brewer.	1. F. K. McClean.	5. A. E. Berriman.
2. J. H. Ledeboer.	6. Alec. Ogilvie.	2. Col. Capper.	6. B. G. Cooper.
3. J. W. Dunne.	7. Mervyn O'Gorman.	3. Lieut. Gregory.	7. Col. Rawson.
4. Major Carden.	8. F. Handley Page.	4. Gen. Ruck.	8. Major Maitland.

* (Enclosed with this issue of the Journal.—ED.)

In June, 1912, five of the non-technical members became associate fellows, thus destroying the balance provided for in Rule 6. The Council, however, did not consider it desirable to call upon five of the technical side to resign (filling their places by non-technical members) as a strict interpretation of Rule 6 might require. For the purposes of retirement at the end of the year, however, the Council decided that the conditions *at the time of election* should govern the retirements, *i.e.*, if a non-technical member who would have retired at the end of the year became technical during the year, he should nevertheless retire at the end of the year (although this might mean that more than four technical members retired).

During the year Mr. Cooper resigned from the Council under Rule 22 to take up the duties of Secretary, and Major Carden also resigned. In the place of these, Mr. W. O. Manning and Major Sykes, respectively, were co-opted under Rule 14.

In accordance with the above interpretations, the retiring members of Council this year are :—

Technical at beginning of year.	Non-Technical at beginning of year.
1. Griffith Brewer.	1. Colonel Rawson.
2. Alec. Ogilvie.	2. A. E. Berriman.*
3. Mervyn O'Gorman.	3. W. O. Manning,* co-opted vice B. G. Cooper.
4. F. Handley Page.	4. Major Maitland.*

* Now Associate Fellows.

Notice was sent to every member under Rule 10 as to the nomination of members for Council. No nominations were received—a contingency for which the rules do not provide. The Council therefore decided that the rules 11 to 13 as to circulation of ballot papers, &c., became inoperative and that the correct procedure was to propose the re-election of the retiring members of Council at the annual general meeting.

This will mean, however, that the Council for 1913–14 will not conform to Rule 6, which provides for a half technical and half non-technical Council.

The Council have wished this position to be fully explained in order that it may be clear that some steps will have to be taken in the future to abolish the provision for the half and half Council, which it will be seen has not worked well in practice. As a matter of fact, at the end of this year there are indications that we shall have a Council of fourteen technical members and two non-technical members.

I will now ask some member kindly to propose the re-election of the retiring members of Council and some member to second this proposition.

Mr. C. C. Turner : I suppose that, strictly speaking, we are out of order in breaking the rule as to the composition of the Council. In the circumstances, however, there seems no alternative but to do this until a favourable opportunity occurs to repeal that rule. It may be said that the absence of other names for election to the Council implies that the members are perfectly satisfied with their present representatives, and I hope the members whom I now have much pleasure in proposing for re-election to the Council will accept the compliment thus implied.

Mr. H. D. Cutler : I have much pleasure in seconding Mr. Turner's proposition.

The motion was put to the meeting and carried unanimously.

Col. Capper : I have much pleasure in proposing a vote of thanks to General Ruck for presiding at this meeting, and I am sure we are greatly indebted to him for the great interest he takes in the Society.

The motion was carried with acclamation and the meeting then terminated.

LIST OF FATALITIES

Date.	Name.	Nationality.	Machine.	Place.
March 5.	.. Geoffrey England	English	Bristol (1)	Salisbury Plain.
April 28	.. Lieut. L. C. Rogers-Harrison	English	Cody (2)	Aldershot
April 21.	Paymaster Eustace R. Berne, R.N., received fatal injuries through being struck by a propeller while on the ground.			

(1) Monoplane. (2) Biplane.

NOTE.

FATALITIES.—Now that flying has become something more than the pursuit of a few experimenters, the recording of its fatalities in this Journal does not serve a useful purpose commensurate with the labour involved in the compilation of the record from among the mass of conflicting reports to be met with concerning any one accident. We have received from a correspondent at the Hague a list of suggested corrections to the lists of the past year, with which it is however not possible to deal, as to do so adequately would require many hours of searching in back records. In future, therefore, British fatalities and others of outstanding scientific interest only will be reported in these pages.

NEW BOOKS AND PUBLICATIONS

THE AVIATION POCKET BOOK FOR 1913. R. Borlase Matthews. London: Crosby Lockwood and Son. 1913. pp. 176. Illus. Price 3s. 6d.

LES AEROMOBILES. R. Goldschmidt. Preface by Ernest Solvay. Paris: H. Dunod et E. Pinat. 1911. pp. 422. Illus.

*LES MOTEURS À COMBUSTION INTERNE. Aimé Witz. Paris: O. Doin et fils. 1913. pp. 336. Figs. Price 5 francs.

LE MOTEUR. (2nd edition). H. Petit. Paris: H. Dunod et E. Pinat. 1912. pp. 600. Figs. Price 8 francs 50.

MECHANISCHE GRUNDLAGEN DES FLUGZEUGBAUES. (Part I.) A. Baumann. München: R. Oldenbourg. 1913. pp. 154. Figs. Price M. 4.

MECHANISCHE GRUNDLAGEN DES FLUGZEUGBAUES. (Part II.) A. Baumann. München: R. Oldenbourg. 1913. pp. 114. Figs. M. 4.

BAU UND BETRIEB VON PRALL-LUFTSCHIFFEN. (Part II.). R. Basenach. München: R. Oldenbourg. 1912. pp. 117. Figs.

LE MOTEUR À EXPLOSION. Capt. C. Martinot-Lagarde. Paris: Berger-Levrault. 1912. pp. 291. Figs. Price 5 francs.

HANDBUCH FÜR FLUGZEUG-KONSTRUKTEURE. C. Haffner. Berlin: Richard Carl Schmidt. 1913. pp. 260. Figs. Price M. 8.

MAGNETO AND ELECTRIC IGNITION. W. Hibbert. London: Whittaker and Co. 1912. pp. 154. Figs. Price 2s.

LES AVIETTES. G. Houard. Paris: La Revue du Cerf Volant. 1913. pp. 30. Illus Price 1 franc.

ETUDE DYNAMIQUE DES MOTEURS À CYLINDRES ROTATIFS. G.-D. Mayer. Paris: H. Dunod et E. Pinat. 1913. pp. 126. Figs. Price 4 francs 50.

* See Review in this issue.

THE ATMOSPHERE. A. J. Berry. Cambridge: University Press. 1913. pp. 146 Illus. Price 1s. net.

LA PHOTOGRAPHIE EN BALLON. Gd. A. Guyer. Paris: Charles Mendel. pp. 30. Illus. Price 60 centimes.

LA PHOTOGRAPHIE PAR CERFS-VOLANTS. H. Quentin. Paris: Charles Mendel. pp. 44. Figs. Price 60 centimes.

LA PHOTOGRAPHIE DOCUMENTAIRE. Paris: Charles Mendel. pp. 79. Illus.

AS EXPERIENCIAS AEROSTATICAS DE BARTHOLOMEU LOURENCO DE GUSMAO. Capt. Gustavo Tedeschi Correa Neves. Lisbon: Aero Club of Portugal. 1913. pp. 55.

VOCABULAIRE DE L'AVIATEUR CONSTRUCTEUR. Paris: F. Louis Vivien. 1911. pp. 143. Price 0.95.

AÉRO-CATALOGUE. (2nd year.) Comment servir dans l'aeronautique militaire. G. le Grand. (2nd edition.) Paris: Société des Publications Sportives. 1913. pp. 141+64. Price 2 francs 50.

CODE TÉLÉGRAPHIQUE INTERNATIONAL DE L'AERONAUTIQUE. Paris: Société des Publications Sportives. 1913. pp. 29. Price 1 franc.

CONFERENCES SUR L'AVIATION MILITAIRE ET NAVALE. C. Lafon. Paris: H. Charles-Lavauzelle. 1912. pp. 123. Figs.

LES AERONEFS SANS CHUTES. A. Remacle. Paris: F. Louis Vivien. pp. 89. Figs. Price

*PRACTICAL AERONAUTICS. Chas. B. Hayward. Chicago: American School of Correspondence. 1912. pp. 769. Illus. Price 15s. n.

LUFTSCHRAUBEN UNTERSUCHUNGEN. F. Bendemann. Part I. 1911. Münich: R. Oldenbourg. pp. 41. Figs.

LUFTSCHRAUBEN UNTERSUCHUNGEN. F. Bendemann. Part II. 1911–12. Münich: R. Oldenbourg. pp. 30. Figs.

DER PROJEKTIERTE FLUG DES LUFTSCHIFFS "SUCHARD" ÜBER DEN ATLANTISCHEN OZEAN. Münich: R. Oldenbourg. 1911. pp. 40. Illus. Price 1 Mark.

WASSERFLUGMASCHINEN. PRAKTISCHER LEITFADEN FÜR FLUGMASCHINEN-KONSTRUKTEURE. Oscar Ursinus. Frankfurt am Main: Verlag des Flugsport. pp. 35. Illus.

VOL DE L'AEROPLANE EN HAUTEUR. Commandant Faraud. Paris: Librairie des Sciences Aeronautiques. 1912. pp. 15. Figs. Price 1 franc.

LA THÉORIE DE L'AVIATION. Robert Gaston. Paris: Librairie des Sciences Aeronautiques. pp. 31. Figs. Price 1 franc 50.

BUILDING AND FLYING AN AEROPLANE. C. B. Hayward. Chicago: American School of Correspondence. 1912. pp. 137. Illus. Price 4s. net.

THE AIR PATROL. Herbert Strang. London: Henry Frowde and Hodder and Stoughton. 1912. pp. 442. Illus. Price 6s.

AERONAUTICAL PROGRESS. Colonel J. D. Fullerton. London: Royal United Service Institution. 1913.

VOLCANOES AND CLIMATE. C. G. Abbot and F. E. Fowle. Washington: Smithsonian Institution. 1913.

TRAVELLING AT HIGH SPEEDS ON THE SURFACE OF THE EARTH AND ABOVE IT. Prof. H. S. Hele-Shaw. Washington: Smithsonian Institution. 1912.

RECENT EXPERIMENTS WITH INVISIBLE LIGHT. R. W. Wood. Washington: Smithsonian Institution. 1912.

MULTIPLEX TELEPHONY AND TELEGRAPHY BY MEANS OF ELECTRIC WAVES GUIDED BY WIRES. Dr. George O. Squier. Washington: Smithsonian Institution. 1912.

RADIOTELEGRAPHY. Commendatore G. Marconi. Washington: Smithsonian Institution. 1912.

INTERNATIONAL AIR MAP AND AERONAUTICAL MARKS. Ch. Lallemand. Washington: Smithsonian Institution. 1912.

ON THE POSITIONS ASSUMED BY BIRDS IN FLIGHT. Bentley Beetham. Washington: Smithsonian Institution. 1912.

THE GYROSTATIC COMPASS. H. Marchand. Washington: Smithsonian Institution. 1912.

LE PILOTAGE D'UN AÉROPLANE. P. Banet-Rivet et P. Leroux. Paris: Gauthier-Villars. 1912. pp. 135. Figs. Price 3 francs 75.

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* See Review in this issue.

REVIEWS

Aéro-Manuel: 1912-13. Par Charles Faroux. (Paris: October, 1912. Dunod & Pinat. pp. 758. 10 francs.)

With the exception of one German year-book, which suffers from a certain want of cohesion and is afflicted with a superabundance of unimportant detail, the Aéro-Manuel edited by M. Faroux is the one aeronautical year-book worthy of the name and of the science that is its subject. It covers almost the whole ground, and does so in a characteristically lucid and well-ordained manner.

The volume—its bulk almost requires the description of tome—opens with a chronology, happily concise until the early part of the year 1910, which is tolerably accurate with the exception of the early English experiments, which are referred to in a singularly unhappy fashion. Thus, Sir George Cayley is stated to have described in *Nicholson's Journal* in 1809 a monoplane with two propellers, the characteristic features were reproduced later in Henson's machine, while in 1886 Wenham is referred to as having built *in collaboration with Stringfellow* a machine with superposed surfaces, which met with no success *because the steam engine was far too heavy*. The latter part of the chronology, however, with its wealth of detail, is most useful and brings one up to August, 1912.

A very complete list of records of every class, while its perusal can only be highly interesting to those of a statistical turn of mind, possesses the homely quality of utility, and the same may be said, though in a different way, of the list of aviation fatalities which, for a wonder, is fairly accurate. A list of the great meetings and competitions, together with the results and times of each race, brings the tabular portion of the work to a close.

The second part is developed to what, for want of a better term, may be referred to as the technique of aviation. It opens with an illustrated glossary—which, unfortunately, is by no means up to date in so far as representative types of aeroplanes or engines are concerned—and further includes with a section entitled "technical notes," professing to give in a brief précis form the main elements of the theory of the aeroplane and the screw-propeller. While I cannot claim to have been impressed with the editor's powers of selection (the entire section consists of abstracts and quotations from well-known writers) either of authors or of works, the difficulties that stand in the way of such a compilation are notorious. On the whole, it would have been far more satisfactory to have rewritten the whole of this chapter and modelled it on simple text-book lines.

A curious side of French journalism, which apparently is also invading literature, is illustrated in the so-called "documentary articles," which are nothing more or less than advertisements drawn up in attractive guise, and may be valued accordingly.

The last section, which is the most extensive, and, in a way, transcends all the rest in value, is statistical and in the nature of a directory. First, there is drawn up in alphabetical order, a list of every name, person, firm or article, with the apposite address, which has even a remote connection with aviation. Next follows a classified trade directory, and finally a complete list of French clubs with their members, and of all foreign clubs with the names of their responsible officials.

Altogether, the work is a monument of industry and patient compilation. It illustrates, as nothing but a trade publication of this nature can, the vast extent of the aviation industry and its numerous ramifications. J. H. L.

Aeroplanes in Gusts, Soaring Flight, and the Stability of Aeroplanes. By S. L. Walkden, (London: E. & F. N. Spon; New York: Spon & Chamberlain. 1912. pp. 188, with 4 plates and 47 woodcuts. Price 7s. 6d.)

It is greatly to be regretted that books and papers are frequently published dealing with problems connected with aviation in which the principles of elementary dynamics are misused, misinterpreted, or even, in some cases, absolutely ignored. The present book seems to be based on a total misconception of the physical significance of the laws for the composition and resolution of accelerations. On page 2 the author gives the following definition:—

"The instantaneous *strength* of gust at any point of the air as regards a given flying machine is measured by the acceleration of headway which any singularity of the air at that point is impressing upon the flying machine and the *direction* of the gust is opposite to the direction of the impressed acceleration."

Now it is quite legitimate in the problem of the man in the mine cage or steam roundabout to compound the acceleration of gravity with an acceleration equal and opposite to that of the cage or roundabout car in order to obtain a result which will determine the pressure of the man on the supporting floor, because in this case the man and car move together and therefore have the same acceleration. In the case considered by Mr. Walkden the air and flying machine move independently, and the only physical connection between them is that caused by the air pressure, which varies (approximately) as the square of the relative velocity, other things being constant, and is further a function of the *direction* of this relative velocity which can only be determined experimentally for any particular aeroplane.

But Mr. Walkden's "acceleration of headway" is, if we understand him right, merely the *rate of change* of the relative velocity, and if we understand him wrong it may possibly not have even this physical significance. It can therefore at the best only determine a rate of change of the pressures acting on the aeroplane, and thus give rise to a rate of change of the acceleration of the machine.

But it is the pressures themselves which are of importance in considering the action of gusts, and to determine these a knowledge of the laws of resistance is essential. Mr. Walkden's treatment thus reminds us of the frequent answers given by weak candidates in examinations which receive no credit because they have failed to make the necessary assumptions in their solutions; indeed, the whole style of the book suggests that the author has not sufficiently assimilated the principles stated in text-books on dynamics. He may have obtained some correct results in connection with wheeling soaring, but it is hardly worth while for a student of aeronautics to wade through the pages when at best he would have to rewrite a great deal of the work in order to obtain results consistent with the subject matter of a college course in applied mathematics.

Under these circumstances it is rather amusing to find a section of *only two pages* headed "Unpractical Lines of Development," and when, in the preface, the author says, "The rate of diffusion of truths in aviation is, however, so very slow that there must be some impediment somewhere. No doubt it will be disclosed or removed with time," we think that readers of the book will cordially agree with him.

G. H. BRYAN.

Les Turbines à Gaz. Par L. Ventou-Duclaux. (Paris: H. Dunod et E. Pinat. 1912. pp. 128. Illus. Price 3 francs 75.)

THE evolution of the gas turbine (which we may trace from the propeller-wheel of the mediæval turnspit) proceeds but slowly, and the problem is still far from being solved, though certain experimental machines have been made to run: it is not, however, to be expected that these should receive commercial consideration until they are able more nearly to approach the present reliability and economy of the steam turbine or gas engine. The author explains that his book is intended as a guide to inventors and experimenters in this field, to give information as to what has been done, and to indicate possible directions of future progress. He appears to have well realised his aim, though it is to be regretted that he does not give more details of actual construction and tests, and of the work which has been done in other countries besides France.

It must however be remembered that few of the experimental results obtained have so far been published.

Chapter I. regards the gas turbine as a combination of the gas engine and steam turbine, which both operate under different conditions and employ different cycles: it explains elementary principles, adiabatic and isothermal curves, Carnot's cycle, reversibility, and maximum theoretical efficiencies, &c.

The author adopts Dugald Clerk's classification of internal combustion cycles, though in a slightly different order:—

(1) Explosion engines without compression (as in the obsolete Lenoir);
(2) Explosion engines with compression (constant volume or isopheric, as in all Otto cycle engines);
(3) Slow combustion engines with compression (constant pressure, or isobaric, as in the old Brayton motor, or the present Diesel engines).

After a brief consideration of entropy, he explains an interesting fact which is often lost sight of, viz., that the present Diesel heavy oil engine does not follow out in practice the idea of "The Rational Heat Engine" as originally laid down by Dr. Diesel, and which was intended to operate on a cycle following Carnot's as far as possible, the reason being that with an isothermal combustion curve the negative work-ratio is excessive, and in order to fatten the work-area diagram it is necessary to sustain the combustion curve at constant pressure instead of constant temperature.

In comparing (p. 23) the efficiencies of different cycles, the author states that (as is well known) for a given initial compression the constant volume cycle gives a better result than that of constant pressure, though in another place he admits that to afford an equable basis of comparison the same maximum pressure should be taken in both cases, since the combustion pressure of the isobaric cycle does not rise above its pressure of compression.

Having divided gas turbines into—

(1) Action, *i.e.*, kinetic energy, where the fluid is supposed to be completely expanded before coming in contact with the blades (as in the de Laval steam turbine);
(2) Reaction, *i.e.*, pressure energy, where the expansion of the fluid takes place in the turbine itself (as in the Parsons steam turbine);

he proceeds to classify their cycles into—

(1) *Discontinuous combustion*, as Wegner, Griepe, Esnault-Petterie, Armengaud, Saint-Beuve, Karavodine, Lentz, and others;
(2) *Continuous combustion*, as d'Arblet, Meineke, and Cook;

and arrives at the conclusion that the discontinuous type will only be of use for small powers without previous compression and for light turbines in which efficiency is only of secondary importance, and that the continuous combustion cycle will be the most suitable for the large gas turbine units of the future. Various methods are considered of lowering the temperature of combustion and expansion:—

(1) By external cooling of combustion chamber with water;
(2) By external cooling of combustion chamber with water and using steam formed
  (a) in a special turbine; or
  (b) in the same turbine;
    (1) By injecting it into the combustion chamber;
    (2) By directing it on to the blades;
    (3) By injecting it into the nozzles;

and Lemâle, Ferranti, Rambal, Windhausen, Holzwarth, Parsons, and others are given as instances.

The author also discusses a turbine utilising the exhaust from a gas engine, as in the experimental gas turbine made by F. W. Lanchester some years ago.

Passing on to methods of compression—

(1) By piston;
(2) By rotary turbo-compressor;
(3) By system of injectors;

he points out that many inventors have rather neglected the compression difficulty, which is really the crux of the problem, because upon the efficiency of the compressor the relation of total to useful work must largely depend. If we use a pump, there seems but little object in not also having a reciprocating motor piston. The injector system does not offer much advantage except for small powers and low pressures. It is therefore upon the improvement of the turbo-compressor that we must rely for the compression of the large volumes of air required.

Chapter III. discusses the laws of fluid expansion and the section shape and length of nozzles for best efficiency, and the influence of pressure variations at the throat. Experiment has hitherto been the chief guide—not much is said about actual nozzle efficiency, though it has been proved by the experiments of Dr. Lucke and others that it it not possible in a nozzle to obtain a temperature-drop at all equivalent to adiabatic expansion behind a piston.

The author omits any detailed consideration as to the method of mixing and burning the fuel: this is, however, an important point, because when we are able to ensure continuous and perfect combustion of gas, oil, or solid fuel, at high pressures and under complete control, the problem will be much simplified.

Chapter IV. comprises 17 pages which give a list of French patents from 1893 onwards; it is noticeable that more of these have been filed for turbines of the discontinuous type owing probably to the influence of the explosion gas engine on the minds of inventors, though of recent years more engineers appear to have interested themselves in the continuous combustion turbine as offering a greater prospect of eventual success.

In conclusion the author sums up his views, and also touches upon the advantages of regeneration, and it is quite conceivable that some regenerative device may be incorporated in the gas turbine of the future more easily than has been the case with the piston engine. A table of contents is given at the end, and also an interesting appendix on the theory of the direct utilisation of kinetic fluid energy in the propulsion of aeroplanes and ships

H. F. L

Practical Aeronautics. By Chas. B. Hayward. (Chicago: American School of Correspondence. 1912. Illus. 769 pp. 15s. n.)

It is now rather late in the day to attempt to compress within the pages of one volume the history, theory, construction and operation of aeroplanes and dirigibles. Such a task is not within the power of any one man to accomplish in a satisfactory manner. Many things must, perforce, be treated perfunctorily, much omitted, and the general result must fail to be authoritative or even reliable.

Mr. Hayward's courageous effort has much to recommend it to the reader for whom it is written, *i.e.*, the student of the American School of Correspondence. At its worst, the book will not lead him far astray; at its best, it is very good indeed. As a fairly complete survey of its subject, it fulfils a purpose, but anyone turning to it for special or minute information will be disappointed. To write this book as it ought to be written would require the collaboration of at least thirty specialists. But while it is too late to pack such a work between two covers, it is too early to write it at all. To-day belongs to the pamphleteer, though only the French and a few Germans are wise enough to realise it.

Practical Aeronautics is divided into eight principal divisions, viz.: Dirigible Balloons, Theory of Aviation, Types of Aeroplanes, Aeronautical Motors, Aerial Propellers, Aeronautical Practice, Building and Flying an Aeroplane, and Aviation and its Future, and no less than 38 subdivisions. The photographs are good and the diagrams excellent.

Mr. Orville Wright, who contributes an introduction, states that "the chapters treating of the work of the early experimenters . . . are remarkably free from the errors usually found in aeronautical works of this character." But the fact that there are at least four errors on the first page does not seem to bear out this statement. Page 2 is no better, as there are four errors in the first two lines. The early history of aviation, too, is full of the small mistakes which always occur in works of this character, and it comes as rather a shock to read under the well-known photograph of Pilcher gliding on the "Hawk" that it is "Lilienthal's gliding apparatus."

The author may, however, be congratulated on his immense industry and his nice sense of proportion, while the bulk of the book is full of really sound matter clearly presented with all the simple directness that reveals the highly-trained teacher. There was never a subject so vast, far-reaching and inexhaustible as aeronautics, and Mr. Hayward, having written this book, will probably be the first to admit it.

T. O'B. H.

Technical Report of the Advisory Committee for Aeronautics, 1911-12. (Wyman and Son, Fetter Lane, London. Price 11s.)

This Report gives a great deal of interesting information, and should be carefully studied by constructors. It contains a general introductory description of the work done during the period under consideration, and detailed reports, &c., by the staff of the National Physical Laboratory and others. Taking the papers *seriatim*, the most interesting ones are:—

No. 54.—The use of models in Aeronautics. This is perhaps the most important of all the papers, as in it an attempt is made to show how the resistance of a full-sized machine can be obtained from the resistance of its model. Various points are considered, and the general idea of the "Law of Similitude" explained. It is shown that for practical purposes, the law is correct as far as the lift, &c., of aeroplanes, their stability, and the action of propellers (unless run at a very high speed) are concerned but that it fails (with our present knowledge) for "Dirigibles" and forms like the body of a bird. The results obtained for these latter forms, as shown by the calculations, are quite unreliable, and could not be depended upon for even approximate estimates.

The reason for this will be best understood by considering the nature of the two classes of resistance which a body moving through a fluid encounters. These are apparently "form resistance" and "skin friction." Since the laws governing them are quite different it is clear that unless they can be separated and accurate values obtained for each it is impossible to apply the law of similitude successfully. Unfortunately this separation has never been properly carried out; we do not know the exact formula for either class of resistance, in fact it is not as yet known whether form resistance exists at all, and consequently any estimate made for the resistance of full-sized machines can only be considered as an approximation. (*See* No. 43 below.)

It is greatly to be hoped that this subject will be further investigated; accurate experiments on "skin friction" are much required; in carrying them out, special care should be taken to see that the "form resistance" does not invalidate the results.

There is a very good account of Froude's "Law of Comparison" in "The Speed and Power of Ships" by D. W. Taylor. Members will find it advantageous to study the chapter dealing with this subject.

No. 53.—Notes on the properties of Aerofoils, &c. In this, the conclusions which may be drawn from published information on aeroplane wing forms are summarised. The main points considered are variations in the shape of the section, aspect-ratio and plan form of a wing; effect of varying the camber of under surfaces; alterations in biplane spacing, result of staggering, &c. Too great camber is found to bring the points of maximum lift and the critical point too close together, thus allowing only a small space for manœuvring; while increase of aspect ratio is shown to be advantageous in curved surfaces. Alteration in the plan form is said not to have much effect, but this requires further investigation, as also does the statement that changing the camber of the lower surface has little or no effect on the value of the lift and drift ratio. There are far better wing sections than those shown in Fig. 2; in fact, it appears possible to get a 30 to 1 lift to drift ratio by suitably designing the under surface of a section something similar to No. 8.

No. 52.—Note on relative frictional resistances of Air and Water. In these experiments air and water were made to flow through the same pipe in such a manner that the viscosity ratio was the same in both cases. Under these circumstances it was found that the coefficients in the equation expressing the frictional force were directly proportional to the densities of the two fluids, thus proving the principle of the dynamical similarity of fluids as far as these particular experiments are concerned. This result is, of course, of considerable importance.

No. 55.—Head resistance of Airship Models, &c. The chief point of interest in these experiments was the truncating of the tails of the models used. It is shown that provided too much was not cut off and that the type of model used was a good one, the resistance was not much increased.

No. 43.—Resistance of Airship Shapes, &c. This gives an account of towing experiments carried out on certain skin models of well-known airships. The velocities varied from 8 to 25 ft. per sec., and actual measurements of the resistances were made. The results are important as very few details of this kind have been published. It should be noticed that the total resistance was of the form

$$R = KV^{1.98}$$

or practically speaking varied as V^2. Now the dimensional equation for the viscous drag on a body moving wholly immersed in a fluid is

$$R = kl^n\rho^{n-1}\eta^{2-n}V^n$$

If we make $n = 2$

$$R = k\rho l^2V^2$$

so that R is *independent of the viscosity*. This seems to show that with bodies of the type experimented with, moving at the velocities mentioned, the law of comparison *does* apply with very fair accuracy. It is to be hoped that in future the reader will not be asked to multiply velocities by $\sqrt{8}\,\sqrt{10{\cdot}1}$, &c.; suitable scales of pressure and velocity for full-sized machines could easily be added to the diagrams.

[N.B.—In calculating the resistance of the Beta at 26 miles per hour see Plate I. The factor 8 is used and not 13·3, as given in line 14, p. 55.]

No. 60.—Experiments on Models of Aeroplane Wings. The object of these experiments was to throw light upon the way in which the forces acting on an aerofoil are built up. To this end three different types of surface were experimented with, and a very thorough analysis of the pressures on the median sections made. The conclusions drawn as regards these particular types were that the design of the upper surfaces is much more important than that of the lower ones, and that the pressure distribution over the upper surfaces is only slightly affected by variations in the design of the lower surfaces. A number of other interesting results were obtained, such, for instance, that the positive pressure on the lower surface and the negative pressure on the upper reach a maximum near the leading edge (as was to be expected) and that both pressures tail off almost to zero at the rear edges. In the appendix the question of the weight of the planes is considered; a matter of some importance as they may easily weigh one-sixth or more of the total weight of a machine. It is to be hoped that some experiments on the pressures all over planes, of different plan forms, will be tried later on, as it will be found that pointed or rounded ends if correctly designed are of considerable importance.

No. 49.—*The wind resistance of aeroplane struts, &c.* A good many details of experiments of this kind have already been published in the Journal, but some of the forms here tested are interesting. The best results were obtained from B.35, an elongated balloon type, R being 6·3 lbs. ; a " Beta " type strut gave R = 6·9 lbs. When the strength of the struts was taken into account the " Beta " was found to be the best with 75, No. 35 being second with 84. When B.35 was tested with thin end forwards, R = 10·9. The correct section for struts is of great importance, the circular section tried had a resistance nearly seven times as great as that of B.35.

No. 58.—*Investigation by visual and photographic methods of flow past plates, &c.* This was investigated in a very ingenious way, and the different types of flow resulting are shown by good photographs. Both air and water were experimented with, and the similarity between the nature of the flow in these two fluids is clearly brought out.

No. 59.—*Experiments with full scale flying machines.* This is a very important paper, as it contains full details of tests made on certain machines in flight. The results are carefully analysed and conclusions drawn as to the best method of improving the machines in question. Excellent plans showing the details of the machines accompany the paper. The machines were a Farman (2), a Santos Dumont (1), and a Bleriot (2), and they were selected merely because they were good types to experiment with. A full account is given of B.E. (2), the combination of results obtained being briefly summarised as follows: (*a*) achieve a speed variation of 75 per cent., (*b*) slow rate of flight 42 miles per hour, (*c*) fast rate 72 miles per hour, (*d*) alight at speeds below 40 m.p.h., (*e*) climb 480 feet per minute for first 1,000 feet, and attain a height of 6,000 feet, (*f*) gliding angle of 1 in 8. It is to be hoped that the question of automatic recording apparatus will be thoroughly gone into later on, as this is a matter of great importance.

No. 64.—*Screw Propeller Theory.* This consists of Rankine's paper on " The mechanical principles of the action of propellers," originally published in the Proceedings of the Institute of Naval Architects 1865, and a commentary by Sir G. Greenhill. Rankine's general theory that every propelling instrument drives a ship, by means of the forward reaction of the current of fluid which it drives back, is of course well known, but there are numerous other considerations affecting the propeller, such, for instance, as the action on the fluid due to the form of the ship, which require careful examination, and concerning which a good deal can be learnt from the paper, and Sir G. Greenhill's remarks. The whole question of propellers is a very difficult one, and as the author says on p. 132, par. 3 : " There is no exact theory, it must be conceded, of universal acceptance for the screw propeller ; reliance is placed chiefly on an empirical factor based on experience and model experiment employed in a formula which satisfies the condition of mechanical similitude, so as to predict from a small scale experiment the performance to be expected from a full-sized machine."

No. 63.—*Experiments on Model Propellers.* This contains very full details of experiments carried out on two Clarke propellers. The paper is a useful one, as the experiments were made when the propellers were in forward motion as well as when they were stationary.

No. 61.—*Some Notes on the possible efficiency of Propellers.* A general discussion on the efficiency of propellers. The theoretical equation on p. 166 should be noted ; it is too often neglected by students.

No. 62.—*Notes on the effect of size on the efficiency, &c., of propellers.* This is largely a discussion on the law of similitude as applied to propellers, and is of considerable interest. The dimensional equations are given, and the circumstances under which the square law can be taken as correct, explained. As stated in considering the first paper, the Law of Similitude is correct enough for practical purposes, unless there is an exceptionally high velocity of rotation.

No. 65.—*Notes on Aerial Propellers.* A useful paper on the design of propellers by Mr. Bolas, the class considered being that proposed by Mr. Drzewiecki, viz. :—the constant angle of incidence type. The ideas are well worked out, and there is a good summary of " procedure in design " which should appeal to constructors.

The remaining papers in this Report give accounts of fabric tests, and the results of a number of experiments conducted by Mr. Dines on the very difficult subject of " Wind Structure." These last are of exceptional interest, as they throw a good deal of light upon one of the most difficult subjects that the aeronaut has to deal with.

The usual Abstracts form a useful appendix to an interesting Report.

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